IDOE

INTERNATIONAL DECADE OF OCEAN EXPLORATION

PROGRESS REPORT VOLUME 4: April 1974 to April 1975

Reports in series:

International Decade of Ocean Exploration,
Progress Report: January 1970 to July 1972,
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Prepared by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, under contract to the National Science Foundation, Office for the International Decade of Ocean Exploration.

October 1975

Nations in IDOE

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Germany, Fed. Rep. of
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Thailand
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United Kingdom
United States
USSR
Venezuela
Viet-Nam, Republic of

PREFACE

The International Decade of Ocean Exploration (IDOE) is a long-term, international, cooperative program to improve the use of the ocean and its resources for the benefit of mankind.

The IDOE was announced on March 8, 1968, when the President of the United States proposed "an historic and unprecedented adventure—an international Decade of Ocean Exploration for the 1970's." In December 1968 the United Nations General Assembly endorsed "the concept of an international decade of ocean exploration to be undertaken within the framework of a long-term programme of research and exploration. . . ."

In late 1969, the Vice President of the United States, in his capacity as Chairman of the National Council on Marine Resources and Engineering Development, formally announced the U.S. intention to contribute to the IDOE and assigned responsibility for planning, managing, and funding the U.S. program to the National Science Foundation (NSF). In charging NSF with this responsibility, the Vice President cited proposed goals relative to man's involvement with the oceans in three broad areas. These were:

- Determine the quality of the ocean environment through accelerated scientific observations of the ocean's natural state, evaluate the impact of man's activity on that environment, and establish a scientific basis for corrective actions necessary to preserve the ocean environment;

- Provide the scientific basis needed to improve environmental forecasting; and

- Determine the potential resources of the sea floor.

An additional program was added during Fiscal Year 1972 to:

- Provide the basic scientific knowledge of biological processes necessary for the intelligent utilization of living marine resources.

One further objective outlined by the Vice President was to:

- Improve worldwide data exchange through modernizing and standardizing national and international marine data collection, processing, and distribution.

In pursuit of this latter objective, the IDOE Office of NSF contracted with the Environmental Data Service (EDS) of the National Oceanic and Atmospheric Administration to manage the scientific data for IDOE. The agreement included publishing this series of reports.

The success of the global IDOE program depends greatly on the extent to which all participating nations contribute their expertise and capabilities. The NSF Office for IDOE has encouraged foreign institutions and researchers to participate in IDOE directly and through the Intergovernmental Oceanographic Commission (IOC) at UNESCO. Scientists and institutions in about 45 nations—in Africa, Asia, Europe, Oceania, and South America—are now participating, and the level of their involvement in these projects is increasing. To encourage greater participation, the Office for the IDOE provides funds

to enable IOC to convene international scientific workshops to consider and, when appropriate, recommend new projects for the IDOE. IOC has recognized IDOE as an important part of its long-term program and has endorsed all NSF-sponsored major projects as key elements of IOC's overall IDOE program.

We are looking forward to continuing oceanographic research efforts under IDOE that place increasing emphasis on international aspects of the program. We hope that in the years to come the IDOE will be remembered as a program that benefited all mankind and set a pattern for many other international ventures to follow.

Feenan D. Jennings, Head
Office for the International
Decade of Ocean Exploration

INTRODUCTION

This report, the fourth in a series, provides the scientific community and other interested persons with information, data inventories, and lists of scientific reports derived from U.S. IDOE projects. The text is arranged according to established program areas for IDOE. Details of subprograms are given under appropriate programs. Ongoing (currently funded) projects are listed. Bibliographies follow subprogram text.

The Appendix contains the National Marine Data Inventory (NAMDI) and the Report of Observations/Samples Collected by Oceanographic Programs (ROSCOP). Both are summaries of reported observations made during the period covered by this Report. During the early part of 1974 the NAMDI data inventory form was replaced by ROSCOP. This new form has been accepted by UNESCO's Intergovernmental Oceanographic Commission (IOC) and put into use by member countries. ROSCOP is similar to NAMDI, but provides for a greater choice of parameters and for identifying the 10° and 1° geographic squares for each data parameter. All IDOE grant holders must now submit ROSCOP reporting forms to NOAA Environmental Data Service's National Oceanographic Data Center (NODC). In the Appendix the ROSCOP's are arranged in the same program sequence as the text.

Two charts follow the Appendix. The first shows ocean areas for which data, NAMDIs, ROSCOPs, and track charts have been received by NOAA's Environmental Data Service (EDS) during the period covered by this report. The second shows ocean areas for which data have been received by EDS from January 1970 to April 1975. Each area is about 600 by 600 nautical miles and, although entirely shaded, may contain only one reported observation.

EDS either has the data, information, track charts, and papers described in this report in one of its center archives or knows where they may be obtained. Queries may be addressed to any of the following EDS centers:

National Oceanographic Data Center (NODC)
National Oceanic and Atmospheric Administration
Washington, D.C. 20235
Tel: (202) 634-7234
IDOE Project Leader: A. R. Picciolo

Marine Geology and Geophysics Branch
National Geophysical and Solar-Terrestrial Data Center (NGSDC)
National Oceanic and Atmospheric Administration
Boulder, Colo. 80302
Tel: (303) 499-6338
IDOE Project Leader: P. J. Grim

Environmental Science Information Center (ESIC)
National Oceanic and Atmospheric Administration
Washington, D.C. 20235
Tel: (202) 634-7334
IDOE Project Leader: W. Hardy

National Climatic Center (NCC)
National Oceanic and Atmospheric Administration
Federal Building
Asheville, N.C. 28801
Tel: (704) 258-2850 Ext. 765
IDOE Project Leader: R. Quayle

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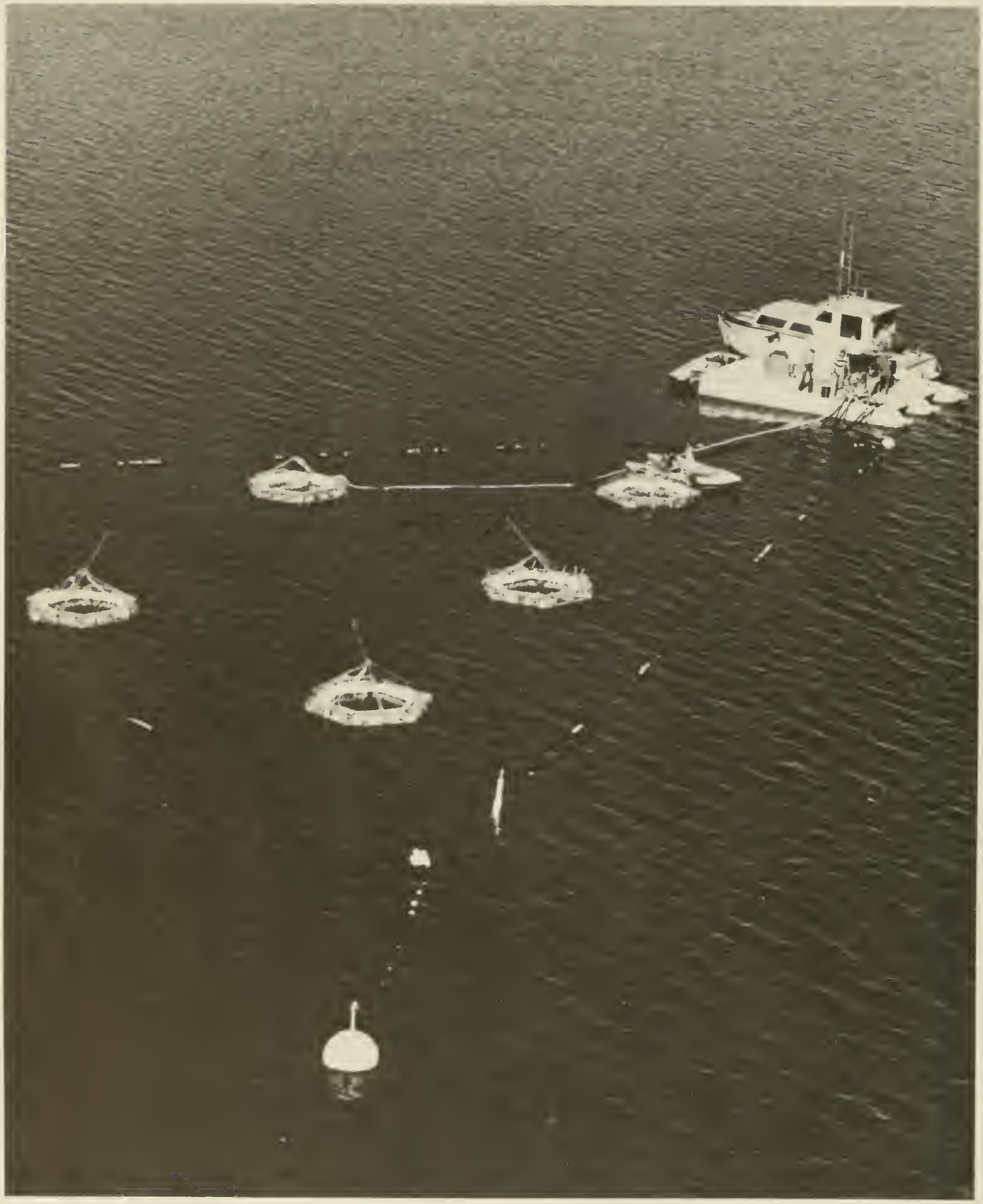


Small-scale plastic enclosures afloat in Saanich Inlet, Vancouver, British Columbia—Controlled Ecosystem Pollution Experiment (CEPEX).

Environmental Quality Program

This program, primarily through research in marine pollution and geochemical processes, is designed to provide information on the quality of the oceanic environment, and the assessment and prediction of man's impact on this environment. The present program consists of three major investigations: the Geochemical Ocean Sections Study (GEOSECS), which is concerned with detailed measurement of physical and chemical characteristics of ocean waters along Arctic to Antarctic sections; Pollutant Transfer Studies, which involve investigations of mechanisms and pathways by which pollutants are transported to and within the oceans; and Biological Effects Studies, which assess the impact of selected pollutants on marine organisms and communities.

Geochemical Ocean Sections (GEOSECS) Study

This international cooperative program involves geochemists at 14 United States universities and from Belgium, Canada, France, Germany, India, Italy, and Japan. Water and suspended material samples collected at selected geographic locations and depths are being analyzed for more than 40 physical and chemical parameters, including: Temperature, salinity, pH, alkalinity, P_{CO_2}, dissolved and trace gases, nutrients, trace metals, dissolved and particulate organic and inorganic matter, natural radionuclides, manmade radionuclides, and stable isotopes. Main survey cruise tracks were along the approximate paths of bottom water currents. At each station, 50 samples of 30 liters each were obtained at selected depths to provide vertical profiles of the properties. At alternate stations, 270-liter samples at 18 to 20 depths were taken for measurements of trace constituents and low-concentration radioisotopes. Information gained from study of the data will improve our understanding of ocean mixing processes. The data also will serve as baselines for assessing future concentration levels of radioactive and other pollutant wastes that are being added to the sea. Projects in this program are listed in table 1.

Atlantic Cruises

Atlantic cruises were conducted from July 1972 to April 1973 by the Woods Hole Oceanographic Institution's RV Knorr and occupied 121 stations. GEOSECS Atlantic legs were reported in *IDOE Progress Report Volume 2: July 1972 to April 1973.*

Pacific Cruises

Pacific cruises were conducted from August 1973 to June 1974 by the Scripps Institution of Oceanography's RV Melville, which occupied 147 stations. GEOSECS Pacific legs 1 through 6 were reported in *IDOE Progress Report Volume 3: April 1973 to April 1974.* Legs 7 through 10 are as follows:

Leg 7. Wellington to Wellington, New Zealand (fig. 1). Sixteen stations were occupied. Four collected large-volume samples, ten small-volume samples, and two STD measurements only.

Leg. 8. Wellington to Papeete, Tahiti (fig. 1.) Twenty stations were occupied. This cruise track crossed the benthic front into "pure" circumpolar water. Observations were made along and across the front until it "died" at 25°S, 155°W and at a depth of 3,300 meters. GEOSECS Pacific cruises have tracked the front for 3,300 miles to this "triple water junction" where South Pacific Deep Water, Equatorial Deep Water, and Antarctic Bottom Water meet.

Leg. 9. Papeete to Papeete, Tahiti (fig. 1). Ten stations were occupied. The first of these served as a calibration cast. In addition to the regular measurements, XBT soundings were made to locate mesoscale eddies in the upper ocean. Data gathered during this leg should provide information about the geographical distribution of the eddies, the mechanism that causes them, and their possible source of energy.

Leg 10. Papeete, Tahiti, to San Diego (fig. 1). Twenty-three stations were occupied, concluding GEOSECS Pacific cruises on June 10, 1974. Closely spaced stations in the vicinity of the Equator revealed the complexity of the zonal-current/counter-current regimes near the Equator.

Shipboard observations for GEOSECS Pacific cruises have not been released to the National Oceanographic Data Center (NODC). Analyses for trace constituents and radioactive materials by shore-based laboratories are expected to require several years until completion. Laboratories which have completed some analyses and have forwarded these data to the GEOSECS data bank at Scripps Institution of Oceanography are listed in table 2.

GEOSECS Bibliography

Amin, B. S., S. Krishnaswami, and B. L. K. Somyajulu, 1974: Th^{234}/U^{238} activity ratios in South Pacific bottom waters. *Earth Planet. Sci. Lett.* 21: 342-344.

Brass, Garrett W. and Karl K. Turekian, 1974: Strontium distribution in GEOSECS oceanic profiles, *Earth Planet. Sci. Lett.* 23(1): 141-148. (GEOSECS Publ. #36)

Table 1.—U.S. institutions, investigators, and projects in GEOSECS program

Organization	Investigator	Project title
Atomic Energy Commission and Woods Hole Oceanographic Institution	H. L. Volchok V. T. Bowen	Fallout Radionuclides in Ocean Water Columns (Sr^{90}, Cs^{137}, $Pu^{238, 239}$)
University of California, San Diego, Scripps Institution of Oceanography	A. E. Bainbridge H. Craig	Operations Group and SIO Shipboard and Laboratory Measurements
Columbia University, Lamont-Doherty Geological Observatory	W. S. Broecker H. Feely P. Biscaye	Analyses of GEOSECS Atlantic and Pacific Samples, Ra^{226}, Ra^{228}, Suspended Particulates (Mineralogy and Chemistry)
University of Hawaii	P. Kroopnick	Isotopic Measurements (C^{13}/C^{12}, O^{18}/O^{16}, D/H) in Dissolved Inorganic Carbon, Dissolved Oxygen, Atmospheric Water Vapor, and Atmospheric CO_2
Louisiana State University	L. M. Chan J. S. Hanor	Barium Analysis in Ocean Waters
Massachusetts Institute of Technology	J. M. Edmond	High-Precision Barium Measurements
University of Miami, Rosenstiel School of Marine and Atmospheric Science	H. G. Ostlund	Radiocarbon and Tritium Measurements
Oregon State University	P. K. Park L. I. Gordon	Nutrient Analyses and Measurements of Organic Carbon and Surface pH
Queens College, The City University of New York	T. Takashashi	Carbonate Chemistry of Seawater
University of Southern California	T. L. Ku	Radium Analysis
University of Washington	M. Stuiver	C^{14} Ocean Water Analysis
Woods Hole Oceanographic Institution	D. W. Spencer P. G. Brewer	Particulates and Trace Elements
	D. W. Spencer	Administrative and Logistic Activities
Yale University	K. K. Turekian	Strontium Analysis
U.S. Naval Oceanographic Office	W. S. Moore	Measurement of Ra^{228} in Seawater

Table 2.—Laboratories conducting trace element and radioactive constituent analyses for GEOSECS

Battelle Laboratories—Northwest, Richland, Wash.
Centre National de la Recherche Scientifique de Faibles Radioactivity, Gif-sur-Yvette, France
Lamont-Doherty Geological Observatory, Palisades, N.Y.
Louisiana State University, Baton Rouge, La.
McMaster University, Hamilton, Ontario, Canada
Oregon State University, Corvallis, Ore.
Physical Research Laboratory, Ahmedabab, India
Scripps Institution of Oceanography, La Jolla, Calif.
University of Hawaii, Honolulu, Hawaii
University of Southern California, Los Angeles, Calif.
University of Washington, Seattle, Wash.
Woods Hole Oceanographic Institution, Woods Hole, Mass.
Yale University, New Haven, Conn.

Broecker, Wallace S., 1974: "No," a conservative water-mass tracer, *Earth Planet. Sci. Lett.* 23(1):100-107.

Chung, Y., 1974: Transient excess-radon profiles in Pacific bottom water, *Earth Planet. Sci. Lett.* 21(3):295-300.

Chung, Y., 1974: Radium-226 and Ra-Ba relationships in Antarctic and Pacific waters, *Earth Planet. Sci. Lett.* 23(1):125-135. (GEOSECS Publ. #34)

Chung., Y., H. Craig, T. L. Ku, J. Goddard, and W. S. Broecker, 1974: Radium-226 measurements from three GEOSECS intercalibration stations, *Earth Planet. Sci. Lett.* 23(1):116-124. (GEOSECS Publ. #33)

Craig, H., 1974: The GEOSECS Program: 1972-1973, *Earth Planet, Sci. Lett.* 23(1):63-64. (GEOSECS Publ. #26)

Craig, H., 1974: A scavenging model for trace elements in the deep sea, *Earth Planet. Sci. Lett.* 23(1):149-159 (GEOSECS Publ. #37)

Horibe, Yoshio, Keiko Endo, and Hiroyuki Tsubota, 1974: Calcium in the South Pacific, and its correlation with carbonate alkalinity, *Earth Planet. Sci. Lett.* 23(1):136-140. (GEOSECS Publ. #35)

Figure 1.—GEOSECS Pacific cruises legs 1 through 10.

Li, Y. H., T. L. Ku, G. G. Mathieu, and K. K. Wolgemuth, 1973: Barium in the Antarctic Ocean and implications regarding the marine geochemistry of Ba and ^{226}Ra, *Earth Planet. Sci. Lett.* 19:352-358.

Longinelli, A., 1973: Decennio Oceanografico Internazionale Progetto Geosecs, *Bolletino Di Geofisica Teorica Ed Applicata* 15(57):82-93.

Ostlund, H. Göte, H. Gorman Dorsey, and Claës G. Rooth, 1974: GEOSECS North Atlantic radiocarbon and tritium results, *Earth Planet. Sci. Lett.* 23(1):69-86. (GEOSECS Publ. #28.)

Roether, W., and K. O. Münnich, 1974: The 1971 transatlantic section of F/S METEOR Near 40° N, *Earth Planet. Sci. Lett.* 23(1):91-99. (GEOSECS Publ. #30.)

Roether, W., 1974: The tritium and carbon-14 profiles at GEOSECS (1969) and GOGO 1 (1971) North Pacific Stations, *Earth Planet. Sci. Lett.* 23(1):108-115.

Silker, W. B., 1974: Air and sea transfer of marine aerosol, Proceedings of 1974 Symposium Atmosphere-Surface Exchange of Particulate and Gaseous Pollutants.

Wong, G. T. F., and P. G. Brewer, 1974: The determination and distribution of iodate in South Atlantic waters, *J. Mar. Res.* 32(1): 25-36.

Pollutant Transfer Studies

Pollutant transfer studies are designed to investigate processes by which pollutants are transferred from land sources to

the oceans and the movement and concentration of pollutants in the oceans. Emphasis is on atmospheric and riverine pathways, and on chemical, biological, and geological processes that affect the distribution and concentration of pollutants. Objectives of studies are to: provide information about the alteration of physical and chemical properties of pollutants, and determine the environmental factors affecting and the principles governing pollutant transfer. Projects in this program are listed in table 3. Some results and ongoing activities of pollutant transfer studies are summarized.

Organization: California Institute of Technology
Investigator: C. C. Patterson
Project title: Determination of the Input and Transport of Pollutant Lead in Marine Environments Using Isotope Tracers
Grant No.: ID074-24362

In cooperation with several other groups of investigators, the principal investigator, has been studying mass balance models of inputs of toxic substances to the Southern California Bight from local urban regions during the past year. Studies were made to determine lead concentrations in water, sediment, and organisms and to determine isotopic compositions for use as tracers in identifying sources of industrial leads.

The absolute amounts of lead collected by aerosol impactors are quite small in offshore regions. Data obtained by other investigators were uncertain because of contamination and analytic error problems. The isotopic composition of the impactor lead samples can be used to identify their sources. For these reasons the principal investigator and associates constructed, cleaned, and used their own impactors to collect aerosols—on an island 25 miles off shore, in the central Los Angeles basin, and at the rim of the mountains around the basin (Mt. Wilson). The investigators have been able to delineate three different types of lead: an ocean atmosphere lead, a Southern California basin atmospheric lead, and a Northern California basin atmospheric lead. This delineation is consistent with prevailing wind patterns.

Other mass-balance-of-lead investigations were concerned with the input of lead to the ocean from storm runoff and wastewater, as well as its deposition in the sediments. Major topics of investigation were:

A. Occurrence of lead in seawater
  1. Speciation of lead in seawater
  2. Isotopic compositions of seawater leads

B. Occurrence of lead in tuna fish

C. Lead-in-seawater workshop

During the past year, a major advance was the discovery that much of the lead in seawater may be adsorbed on the mucilage of algae. In higher organisms lead is adsorbed on the albuminoid slime of the epidermis.

Table 3.—U.S. institutions, investigators, and projects in Pollutant Transfer Studies program

Organization	Investigator	Project title
California Institute of Technology	C. C. Patterson	Determination of Input and Transport of Pollutant Lead in Marine Environments Using Isotope Tracers
University of California, Bodega Marine Laboratory	R. Risebrough	Formulation of Mass Balance Equations for Polychlorinated Biphenyls in Marine Ecosystems
University of California, Scripps Institution of Oceanography	E. Goldberg	Fluxes of Synthetic Organics in the Marine Environment
	R. Lasker*	Exchange Rates of Chlorinated Hydrocarbons and Similar Chemicals in Marine Food Chains Established in the Laboratory
University of Georgia, Skidaway Institute of Oceanography	H. L. Windom	Transfer of Heavy Metals Through the Inner Continental Shelf to the Open Ocean
Harvard University	J. N. Butler	Transfer of Persistent Pollutants in Sargassum Communities
San Jose State University	J. H. Martin	Cadmium Transport to the Open Pacific Ocean via the California Current System
Texas A & M University	B. J. Presley	Quantities and Forms of Pollutants Carried by the Mississippi River and Their Fate in the Gulf of Mexico
University of Rhode Island	R. A. Duce	Atmospheric Pollutant Transfer and Deposition on Sea Surface
Woods Hole Oceanographic Institution	G. R. Harvey	Uptake and Transfer of Chlorinated Hydrocarbons in the Atlantic Ocean

* National Marine Fisheries Service

Organization: University of California, Berkeley
Bodega Marine Laboratory
Investigator: R. W. Risebrough
Project title: Formulation of Mass Balance Equations for Polychlorinate Biphenyls in Marine Ecosystems
Grant No.: GX-32885

Baseline studies were carried out to determine the extent of chlorinated hydrocarbon contamination of marine ecosystems, principally in the Pacific Ocean. These new studies extended and complemented those carried out previously by the investigator on chlorinated hydrocarbon contamination of California coastal waters.

Birds have been used extensively in the investigator's baseline studies. The principal reason has been the knowledge of chlorinated hydrocarbon levels among the California coastal species occupying various ecological niches. Samples of the same species from other areas of the Pacific or from closely related species occupying similar or identical ecological niches have permitted comparison of pollutant levels.

These investigations were broadened to include several studies of heavy metal distributions. These were needed to determine whether ecological damage might be caused in part by one or a combination of heavy metals.

Organization: Harvard University,
Bermuda Biological Station
Investigator: J. N. Butler and B. F. Morris
Project title: Transfer of Petroleum Residues in Sargassum Communities and the Waters of the Sargasso Sea
Grant No.: GX-32883

The most visible and easily studied oceanic pollutants are the solid pelagic tar lumps found at the ocean surface. The fate of this material through physical disintegration, chemical degradation, and biological metabolism and uptake is poorly known and may have substantial long-term effects on the oceanic ecosystem. Work to date has included: characterization of composition of tar lumps by gas chromatography; publication of a summary report on known information regarding pelagic tar, and an identification manual of fauna of the *Sargassum* community; separation of over 300 *Sargassum* communities into taxa; elucidation of the basic food web within the *Sargassum* community; and extraction and analysis of hydrocarbons from *Sargassum* alga and some associated organisms.

Organization: San Jose State University
Investigator: J. H. Martin
Project title: Cadmium Transport to the Open Pacific Ocean Via the California Current System
Grant No.: IDO75-01303

This 2-year study, begun late in 1974, is projected to be a multidisciplinary study of the California Current, using cadmium as an example pollutant. The California Current flows southward along the west coast of continental United States and, after passing Baja California, turns west and joins the North Equatorial Current. Pollutants from rivers, outfalls, and atmospheric fallout can become entrained in these waters and transported to the open Pacific Ocean. Cadmium was chosen for its well-known toxicity and because input levels off Southern California are high. The investigator has consistently found elevated levels of cadmium in plankton off Baja California.

Organization: University of Rhode Island
Investigator: R. A. Duce
Project title: Atmospheric Pollutant Transfer and Deposition on the Sea Surface
Grant No.: IDO72-06425

The principal investigator's and co-investigator's stated objectives and scope of research are to:

1) evaluate the importance of atmospheric transport of such pollutants as heavy metals, petroleum products, and chlorinated hydrocarbons to the ocean surface;

2) characterize the surface microlayer of the ocean with respect to chemical concentration and speciation of naturally occurring and pollutant organic and inorganic substances;

3) characterize the top 1 meter of the ocean with respect to certain chemical concentrations and physical features, such as density stability; and

4) study—by laboratory investigations—chemical and physical mechanisms of pollutant concentration, stabilization, and dispersion in the surface layer of the ocean.

The past year's work led to the following developments in instrumentation, analytical methods, and results of analyses.

1) Developed and put to use automatic atmospheric sampling systems.

2) Developed techniques to collect sea surface microlayer samples. These are being tested.

3) Devised six techniques or laboratory methods to separate and identify atmospheric pollutants.

4) Obtained and analyzed data that provide tentative conclusions on "gaseous" atmospheric hydrocarbon values, surface enrichment of chlorinated hydrocarbons, and enrichment and distribution of trace metals in the North Atlantic atmosphere and sea surface microlayer.

Field observations during the past year were accomplished by the University of Rhode Island's RV Trident—cruises 145, 147, and 152—and from the Bermuda tower facility.

The following summary identifies items submitted to NOAA Environmental Data Service's National Oceanographic Data Center.

NODC Accession No.: 75-0528

1) Table of trace metals in 68 samples of surface microlayer particulate matter (Fe, Al, Cu, Cr, Zn, Mn, Pb, Cd).

2) Table of trace metals in 99 samples of atmospheric particulate matter (Fe, Al, Cu, Cr, Zn, Mn, Pb, Cd).

3) Table of alkali and alkaline earth trace metals in 99 samples of atmospheric particulate matter (Na, Mg, Ca, K).

4) Table of trace metals in 180 samples of atmospheric particulate matter collected from the Bermuda tower (Fe, Al, Cu, Cr, Zn, Pb, Cd).

5) Table of alkali and alkaline earth trace metals in 180 samples of atmospheric particulate matter collected from the Bermuda tower (Na, Mg, Ca, K).

6) Table of mercury determinations in four samples of surface sea water.

7) Table of mercury concentrations versus depth at four stations in the Northwest Atlantic Ocean.

8) Table of mercury concentrations in coastal waters off the northeastern United States (10 samples).

9) Table of hydrocarbon concentrations in 14 samples collected in the sea surface microlayer and subsurface (RV TRIDENT cruise 145).

10) Table of hydrocarbon concentration in 36 water samples collected during RV TRIDENT cruise 152.

11) Table of chlorinated hydrocarbons in 39 Bermuda air samples (PCB, pp-DDT, cis-+trans-chlordane, dieldrin, toxaphene).

12) Table of chlorinated hydrocarbons in 13 RV TRIDENT air samples (PCB, pp-DDT, cis-+trans-chlordane, dieldrin, toxaphene).

13) Table of chlorinated hydrocarbons in six water samples collected during RV TRIDENT cruise 145 (PCB, pp-DDT).

Organization: Woods Hole Oceanographic Institution
Investigator: G. R. Harvey
Project title: Input and Loss of Petroleum and Chlorinated Hydrocarbons to the Deep North Atlantic Ocean
Grant No.: IDO72-06435

Contamination of the oceans by petroleum and chlorinated hydrocarbons provides the basis for geochemical tracer experiments. Movements of these stable compounds (tracers) through oceanic cycles in the Atlantic Ocean are being studied. The investigator and coworkers, from previous work, have gained a reasonable knowledge of quantities of these contaminants in the mixed layer of the Atlantic Ocean, especially the North Atlantic. However, little is known about continental inputs of hydrocarbons to the ocean, except by wind transport, or about transport to or concentrations in the deep sea. These processes are being studied, using both types of hydrocarbons, through analyses of water, sediment, and benthos samples from continental shelf, continental slope, and deep-sea areas of the North Atlantic. Objectives are to estimate rates at which these organic contaminants are entering the sea from land and air, their residence time in the water column, and their rates of loss from seawater by burial in the sediments. Ultimate objectives are to forecast oceanic environmental quality, using data gathered by international monitoring programs. During the past 2 years, significant progress has been made in analyses of nearshore, slope, and deep-sea sediment and water samples, and in collection of abyssal plain benthos samples for analysis. Samples used in this research were collected during three cruises by the RV ATLANTIS and one cruise by the RV KNORR (fig. 2).

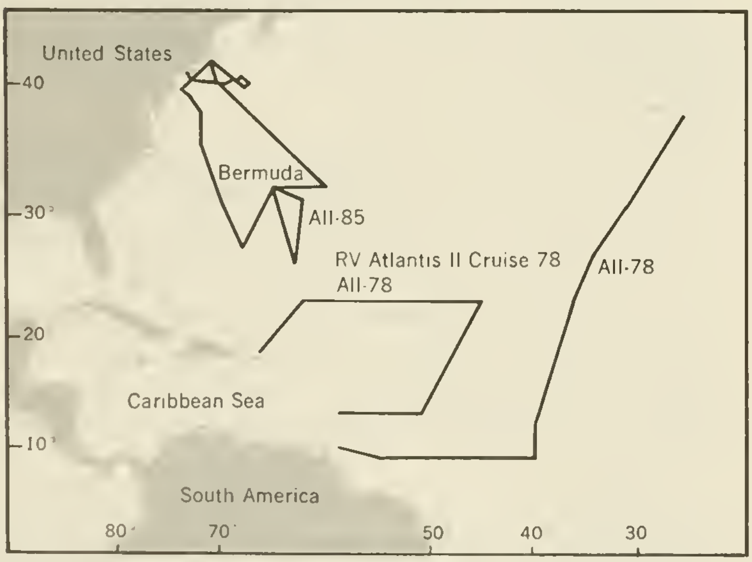


Figure 2.—Woods Hole Oceanographic Institution cruise tracklines—Input and Loss of Petroleum and Chlorinated Hydrocarbons to the Deep North Atlantic Ocean study.

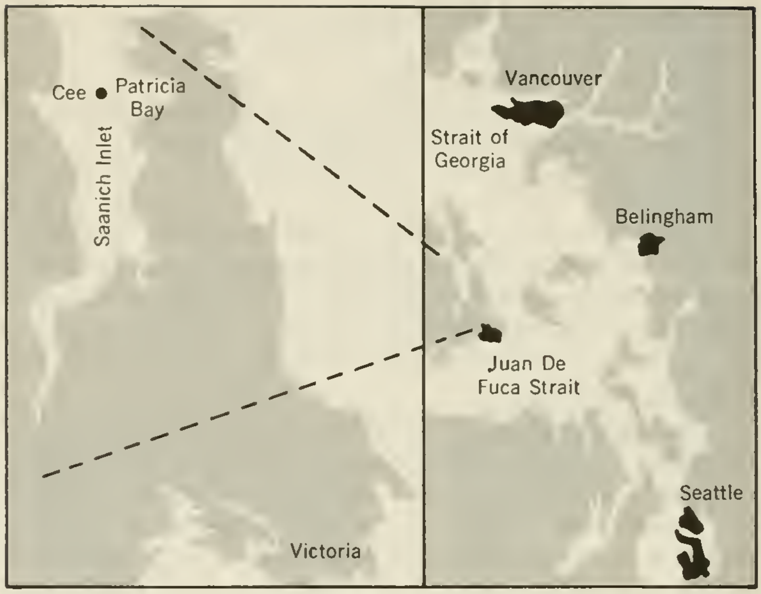


Figure 3.—Saanich Inlet site of CEPEX experimental enclosures.

Biological Effects Studies

The purpose of these studies is to investigate the effects of pollutants on marine organisms and ecological communities. Both laboratory and field experiments are included. Laboratory work is concerned mainly with effects of pollutants on single classes of organisms. Field studies are integrated into the Controlled Ecosystem Pollution Experiment (CEPEX). This cooperative research project of international scope involves trapping water and natural communities in large plastic enclosures (10 m diameter by 30 m deep) and assessing the effects of added pollutants on marine ecosystems—the long-term effects influencing the stability of marine populations. The initial CEPEX enclosures are located in Saanich Inlet, Vancouver Island, British Columbia (fig. 3). Projects relating to biological effects studies and CEPEX are listed in tables 4 and 5, respectively. Project summaries follow.

Organization: University of Georgia
Skidaway Institute of Oceanography
Investigator: R. F. Lee
Project title: Fate of Petroleum Hydrocarbons in the Marine Food Web
Grant No.: GX-42482

Various species of phytoplankton, zooplankton, fish, and benthic invertebrates are subjected to suspensions and solu-

Table 4.—U.S. institutions, investigators, and projects in Biological Effects Studies program

Organization	Investigator	Project title
University of California, Scripps Institution of Oceanography	T. J. Chow	Assimilation of Lead, Cadmium, and Thallium by Marine Organisms With Consideration to Biological Effects
Florida State University	J. A. Calder	Investigations of Breakdown and Sublethal Biological Effects in Trace Petroleum Constituents in the Marine Environment
University of Georgia, Skidaway Institute of Oceanography	R. F. Lee	Fate of Petroleum Hydrocarbons in Marine Food Web
Oregon State University	R. L. Holton	Dynamics and Effects of Polychlorinated Biphenyls in Marine Food Chains
Texas A & M University	J. W. Anderson	Sublethal Effects of Selected Heavy Metals and Organic Compounds on Organisms From the Gulf of Mexico
	C. S. Giam	Isolation, Characterization, Quantitation, and Biological Effect of Phthalates and Chlorinated Hydrocarbons in Biota From the Gulf of Mexico
	W. M. Sackett	Fate and Spatial and Temporal Distribution of Petroleum-Derived Organic Compounds in the Ocean, and Their Sublethal Effects on Marine Organisms
University of Texas, Marine Science Institute	J. A. C. Nicol and C. Van Baalen	Marine Petroleum Pollution: Biological Effects and Chemical Characterization

Table 5.—U.S. institutions, investigators, and projects in Controlled Ecosystem Pollution Experiment (CEPEX)

Organization	Investigator	Project title
University of Alaska, Marine Science Institute	J. J. Goering A. Hattor	Nitrogen and Silicon Regeneration in Controlled Aquatic Ecosystems
University of California at San Diego, Institute of Marine Resources	J. R. Beers	The Role of Microzooplankton in an Environmental Effects Program
	R. W. Eppley	Kinetics of Nutrient Assimilation by Phytoplankton
University of California, Scripps Institution of Oceanography	O. Holm-Hansen W. H. Thomas	Effects of Pollutants on Marine Phytoplankton
University of Georgia, Skidaway Institute of Oceanography	D. W. Menzel H. L. Windom	Integrated Field Studies and Operations Heavy Metal Variations in Natural and Polluted Ecosystems
University of Miami, Rosenstiel School of Marine and Atmospheric Science	M. R. Reeve	The Role of Zooplankton in an Environmental Effects Program
Woods Hole Oceanographic Institution	G. W. Grice R. F. Vaccaro	Zooplankton Population Assessment The Complementary Role of Heterotrophic Microbial Measurements in an Environmental Effects Program

tions of paraffinic and aromatic hydrocarbons in seawater under both laboratory and field conditions. The uptake, metabolism, storage, and discharge of the hydrocarbons by members of the food web and their passage from one trophic level to the next are then studied. Field studies include the addition of radioactive and nonradioactive hydrocarbons to sections of a marsh and to a pelagic area enclosed in a large bag. Activities include:

1) Addition of various aromatic hydrocarbons, including benzpyrene, methycholanthrene, and napthalene to seawater containing zooplankton and, after uptake from the water, observations of storage and/or discharge of hydrocarbons by the zooplankton.

2) Studies of zooplankton collected at CEPEX site and from Arctic and California waters.

3) Studies of effects of petroleum hydrocarbons on organisms in CEPEX experimental enclosures—in cooperation with CEPEX participants.

4) Studies on the occurrence of benzpyrene in oysters, blue crabs, and marine catfish—in cooperation with the National Cancer Institute. Benzpyrene is a polycyclic aromatic hydrocarbon in crude oil and petroleum combustion products.

5) Analyses of biogenic hydrocarbon in a variety of organisms.

Organization: Texas A & M University
Investigators: J. W. Anderson, J. M. Neff
Project title: Effects of Pollutants on Gulf of Mexico Organisms
Grant Nos.: GX-37344, GX-37347, GX-37349

Extensive research was conducted on the effects of sublethal levels of several classes of pollutants—petroleum hydrocarbons, polychlorinated byphenyls, phthalate esters, and heavy metals. In addition, acute toxicity studies were conducted to prepare for the sublethal effects experiments. Examples of this work follow.

Acute Effects—Toxicity: The 96-hour LC-50 values have been determined to allow a more intelligent selection of concentrations to be used in sublethal effects work. Since earlier literature references to toxic concentrations varied greatly in methodology, analytical capabilities, and other significant factors it was deemed necessary to perform this basic bioassay work. It has been determined that the heavy metals tested, as well as the PCB Aroclor 1254, are toxic to the primary test species (*Palaemonetes pugio* and *Cyprinodon variegatus*) at levels in the low ppm range (1-10 ppm). Whole oils have shown significantly lower toxicity to these species (50-100 ppm range). Phthalates pose a special physical problems as to solution in test medium and losses. Certain specific petroleum hydrocarbons are more toxic than whole oils. The naphthalenes, for example, have 96-hour LC-50 values in the high ppb range (0.8 ppm). Benzene and toluene appear to be of relatively low toxicity (20 ppm for *Cyprinodon*).

Sublethal Effects. Studies of sublethal effects on selected activities, functions, and life stages of various organisms included the following.

a. Oxygen consumption: Experiments were conducted with two species each of fish, crustaceans, and molluscs. Results of these studies have indicated that respiratory response is not consistent under these conditions and, therefore, it was concluded that for these particular purposes, measurement of this parameter is less useful than others investigated.

b. Feeding behavior: No effects of mercury on the rate at which crabs *Petrolisthes armatus* consumed *Artemia* nauplii were detected. These results may be due to inadequate sampling of *Artemia.* Aroclor 1254 at a concentration of 1.0 ppm significantly decreased the rate at which the mussel *Brachidontes recurvus* filtered the green flagellate *Platymonas* from the medium.

c. Chloride ion regulation: Levels of blood chloride were determined in experiments in which test animals (*Palaemontes pugio*) were either exposed to a pollutant in seawater at the acclimation salinity (salinity maintenance) or exposed and then transferred to a range of salinities from 1-35‰ (salinity shock). In these experiments it has been determined that:

1) Blood chloride levels of adult *P. Pugio* acclimated to salinities of 1-35‰ and exposed to ppb of Aroclor 1254 were not affected (maintenance).

2) Exposure of juvenile *P. pugio* to the same concentration of Aroclor 1254 depressed blood chloride levels in those shrimp acclimated to 1 and 7‰. This effect was not observed at higher salinities to 31‰.

3) Salinity-shocked juveniles which had been exposed to Aroclor 1254 were less able to adjust blood chloride ion levels compared with controls.

4) Mercury at 100 ppb did not affect chloride levels in blood of *P. pugio.*

5) Blood chloride regulation by *P. pugio* was also apparently unaffected by exposure to 50 ppb of cadmium.

6) Mercury at 50 ppb did not affect the ability of *Petrolisthes armatus* to maintain or adjust blood chloride levels in these experiments.

7) Exposure to mercury at a concentration of 500 ppb for 2 hours in natural seawater aboard Texas A&M's RV Gyre resulted in a significant difference between blood chloride levels of salinity shock experimental and control animals.

The importance of internal volume changes in the chloride ion balance is currently being investigated by the ^{14}C-inulin technique.

d. Larval survival, growth, and development: Studies have been conducted and are in progress as to the effects of pollutants on the survival, growth, and development of larval or juvenile organisms. Among the results obtained are:

1) Exposure of *P. pugio* to 10 ppb of Aroclor 1254 significantly prolongs the amount of time from hatching to the postlarvae stage as compared with controls. No physical abnormalities were observed.

2) *Cyprinodon variegatus* fry exposed to 1.0 ppb of mercury for 63 days were not significantly different in size compared with unexposed controls. Toxic levels for fry are 3 orders of magnitude less than for adults.

3) The effects of exposure to 0.5 and 1.0 ppb of mercury on penaeid (*Penaeus*) postlarvae are currently being investigated.

e. Shipboard experiments: On a recent cruise in the Gulf of Mexico aboard Texas A&M RV Gyre, the following experiments were conducted:

1) The uptake and accumulation of mercury from natural seawater by bivalved molluscs and penaeid shrimp.

2) The effects of mercury on the rate of oxygen consumption of these species.

3) The change in chloride ion levels of penaeids and crabs immediately after collection and at time intervals thereafter.

4) The effect of combined mercury exposure and salinity shock on the chloride ion concentrations of the blood of shrimp.

Numerous biological samples were also obtained for baseline

pollutant determinations to be performed in the laboratories of C. S. Giam, B. J. Presley and W. M. Sackett.

Organization: University of Texas
Marine Science Institute at Port Aransas
Investigator: J. A. C. Nicol and Chase Van Baalen
Project title: Marine Petroleum Pollution: Biological Effects and Chemical Characterization
Grant No.: GX-37345

The investigators are continuing studies using some of the commonly available animals of the Texas coastal region These investigations include the effects of petroleum on sperm, egg permeability, fertilization, cleavage, early development of embryos, feeding, and cardiac responses.

In research dealing with microalgae, it has been found that some microalgae are quite sensitive to water solubles from petroleum pollutants. Sensitive forms may slowly adapt and become less sensitive. This information is based on work with pure cultures. A possible influence of a bacterial and fungal population on the chemical composition of oil is that they may alter toxic materials and thereby allow algal growth. Microalgae also may be able to metabolize and possible detoxify aromatics. On the other hand, aromatics apparently are degraded slowly and with difficulty by bacteria or fungi. They may accumulate with chronic spills.

Variations in the observed toxicity of different oils suggest that it is as important to know the type of oil as it is to know the concentration. Uncertainties about weathering of oils, microbial degradation, and input of natural biogenic hydrocarbons make determination of low-level petroleum concentrations difficult. For these reasons the investigators are attempting to characterize a few of the agents in oils that demonstrate the greatest toxicity to test organisms.

Organization: University of Alaska
Institute of Marine Science
Investigator: John J. Goering
Project title: Nitrogen and Silicon Regeneration in Controlled Aquatic Ecosystems (CEPEX)
Grant No.: IDO 75-03678

The objective of this study is to determine the effects of low levels of pollutants (e.g. heavy metals, hydrocarbons) on the rates of nitrogen and silicon regeneration in pelagic marine ecosystems to provide a scientific basis for determining deleterious effects on nutrient regenerative processes. It is planned to use the ^{15}N and ^{30}Si stable isotope tracer methods to measure the various regeneration rates. ^{15}N will be used to measure: 1) total ammonium production by bacterial decomposition of organic matter and by zooplankton excretion, 2) utilization of ammonium by phytoplankton and other microorganisms, 3) bacterial oxidation of ammonium to nitrite, 4) bacterial oxidation of nitrite to nitrate, and 5) bacterial and phytoplankton production of nitrite by reduction of nitrate. ^{29}Si and ^{30}Si will be used to measure 1) silicic acid uptake by silicon requiring phytoplankton and 2) silicic acid production by dissolution of silica containing phytoplankton.

Organization: University of California at San Diego
Institute of Marine Resources
Investigator: John R. Beers
Project title: Microzooplankton in the Controlled Environment Pollution Experiment (CEPEX)
Grant No.: GX-39145

The taxonomic composition, numerical abundance, and biomass of the populations of small animal plankton were monitored during all quarter-scale CEE (CEPEX experimental enclosure) studies conducted in 1974. In general, changes in the microzooplankton taxa and their abundances in two unperturbed CEE plankton populations monitored for a month during the replication study (May 2 to 30) were very similar throughout the period of observation. In the first study of the effects of copper (June 16 to July 12) the numbers and biomass of both the protozoan and metazoan fractions of the populations dropped to lower levels in the CEEs with copper (10 and 50 ppb) compared with the control containers. The effects on various microzooplankton taxa were generally more extreme, the response more rapid, and recovery, if any, slower at the higher copper level. In a second experiment testing copper at 5 and 10 ppb (September 3 to-30), metazoans, principally copepod nauplii, were generally somewhat lower in abundance in the 5 ppb Cu CEE relative to the control. A more marked difference was seen at 10 ppb. However, protozoa at 10 ppb Cu, although dominated by a different species of oligotrich ciliate than the control, didn't show marked differences from the control in the total ciliate biomass until the last week of observation, when very rapid growth was seen in the copper-containing CEE. (CEE samples of 5 ppb Cu have not yet been analyzed for the protozoa.) Neither the protozoan or metazoan components of the microzooplankton showed marked and consistent differences in total population dynamics-between the controls and either of the "experimental" CEEs during the study on the effects of petroleum hydrocarbons (August 2 to 27).

Organization: University of California at San Diego
Institute of Marine Resources
Investigator: R. W. Eppley, W. G. Harrison, and E. H. Renger
Project title: Kinetics of Nutrient Assimilation by Phytoplankton (CEPEX)
Grant No.: IDO74-04838

The project objective is to assess the kinetics of nutrient uptake by phytoplankton. Field work by the investigators at the CEPEX site (Saanich Inlet, Sidney, British Columbia) has shown that uptake rates of ammonium and nitrate by phytoplankton were largely regulated by ambient levels of the nutrients in the water. Ammonium assimilation was approximately equivalent to that of nitrate, in spite of the fact that only nitrate was added at intervals to fertilize the CEEs. Mineralization was obviously important in releasing ammonium from the settled phytoplankton and perhaps also in the enclosed water column. Copper was inhibitory to nitrate uptake for a few days, following its addition. This was not observed after 2 to 3 weeks, by which time shifts in phytoplankton species composition were observed. Synthesis of nitrate reductase, induced by nitrate, was inhibited by copper at 10 ppb in the samples of Saanich Inlet water but not in phytoplankton samples from CEEs taken after the species composition shift. Bioassays of copper sensitivity, using photosynthesis measurements showed that phytoplankton from copper-containing CEEs became resistant to copper in proportion to ambient levels.

Organization: University of California
Scripps Institution of Oceanography
Investigator: William H. Thomas, Osmund Holm-Hansen, and Farooq Azam
Project title: Effects of Polutants on Marine Phytoplankton and Bacterial Communities (CEPEX)
Grant No.: GX-39139

Field work with quarter-scale CEEs commenced in 1973 with replication and sampling experiments. The biological events in four CEEs replicated well in May 1974. Effects of Cu on natural algal communities at Scripps (winter 1974) showed that crops and photosynthesis were decreased at about 10 ppb Cu. Cu in CEEs inhibited algal crops and photosynthesis and bacteria activities initially but both populations recovered after one month incubation. The dominant algae changed, so that microflagelates were more abundant in Cu-treated CEEs, while diatoms were abundant in control CEEs. Resistance to Cu was found in the bacterial population after prolonged inhibition and Cu-treated bacteria were also Hg-resistant. The elemental and gross chemical composition of the microbial crop did not change as a result of Cu treatment. ATP levels followed the phytoplankton crop changes. Cu/ATP ratios did not change which indicated that algal cells were not killed but that Cu was algistatic. Hydrocarbons added to CEEs caused an initial increase in the algal crop and photosynthesis but this was not a strong effect. Bacteria were inhibited by petroleum hydrocarbons and did not develop resistance to them. Inhibition depended on the concentration and type of hydrocarbon. In small scale experiments Hg inhibited a dinoflagellate crop at about 1-5 ppb.

Organization: University of Miami, Rosenstiel School of Marine and Atmospheric Science
Investigator: M. R. Reeve
Project title: The Role of Zooplankton in an Environmental Effects Program (CEPEX)
Grant No.: GX-39140

Short-term (24 hours) L. D. 50 concentrations for mercury and copper were determined for a variety of zooplankton. For a single species, and amongst species, L. D. 50 concentrations were inversely proportional to size, with mercury some 2 to 4 times more toxic than copper. These data suggest that the critical effects of a toxicant will be manifested on the youngest stages of any species and possibly its eggs, and in the trophic sense at the microzooplankton level of the food chain. Offshore species of copepods were slightly more sensitive than inshore zooplankton (for the same size) with the exception that a ctenophore was the most sensitive organism tested for its size. The least sensitive species on this basis was a rotifer. During the two copper experiments at Saanich, significant sub-lethal effects on the feeding, respiration and phosphorous excretion of a variety of zooplankton were demonstrated after exposure to copper concentrations as low as 5 ppb, even when the organisms did not show any mortality during the course of the experiment. The CEEs were shown to permit conditions far more natural than laboratory environments for the maintenance of natural zooplankton populations. Growth and egg-production occurred in the CEEs as well as photoplankton control by herbivore grazing and hervibore control by carnivores.

Organization: Woods Hole Oceanographic Institution
Investigator: G. D. Grice
Project title: Zooplankton Population Assessment (CEPEX)
Grant No.: IDO74-0515

As part of the CEPEX program, this investigator is currently analyzing the results of three experiments conducted from April to October 1974 at the CEPEX site at Saanich Inlet, B. C.: a replication study and two copper experiments in which Cu (as $CuSO^4$) was introduced to produce concentrations of 10 and 50 ppb and 5 and 10 ppb, respectively. The studies were performed in polyethylene cyclinders (CEEs), each containing approximately 66 m^3 of seawater.

The replication experiment was designed to assess the precision and accuracy with which zooplankton population abundance could be estimated within a CEE. Two sampling devices were tested: a 20-cm modified Bongo net (202 μm) for collecting integrated samples from 14 m to the surface, and a Schindler trap for obtaining discrete samples from 14 m, 7 m, and just below the surface. Samples from these two devices were compared with samples collected by pumping all of the water from the CEE through a 202 μm net. Statistical analysis of the samples showed that both Bongo and Schindler samplers provide an acceptable level of precision and accuracy for the determination of population size and fluctuations. It was concluded that Bongo collections are the best means of estimating zooplankton densities in a CEE, while the Schindler trap can be used to investigate vertical distribution and other aspects of plankton patchiness.

Analysis of samples from the first copper experiment has recently been completed. Total counts show that the zooplankton in control CEEs declined during the month-long experiment, probably as a result of grazing by ctenophores and medusae. Zooplankton decrease in the two experimental (10, 50 ppb copper) CEEs was, however, significantly more rapid than in the control CEEs. The effect was more pronounced in the CEE with the addition of 50 ppb Cu than in the one with an addition of 10 ppb.

Diversity indices were computed for all samples, but no significant trends were evident, despite both a marked decline in total numbers and changes in speces dominance. Samples were also compared by similarity index. A dendrogram constructed by cluster analysis of similarity coefficients for unweighted paired samples showed that the samples are divided into two groups, polluted and unpolluted. Samples from the two control CEEs, and samples from the experimental enclosures prior to the addition of copper are more closely related to one another than to samples obtained from the experimental CEEs after the addition of copper.

Organizaion: Woods Hole Oceanographic Institution
Investigator: Ralph F. Vaccaro
Project title: The Complementary Role of Heterotrophic Microbial Measurements in an Environmental Effects Program (CEPEX)
Grant No.: GX-39147

Readily available species of ^{14}C-labelled organic substrates at trace concentrations are used to experimentally assess heterotrophic microbial activity. Studies are being conducted in the

laboratory and at the CEPEX installations in Saanich Inlet, British Columbia, Canada. Kinetic uptake patterns obtained by this technique permit an assessment of appropriate parameters that uniquely and sensitively describe organic carbon assimilation in a variety of experimentally defined situations.

Studies completed the past summer at Saanich Inlet were to determine the effects of copper on the local marine community. Present indications are that copper concentrations within the range 10 to 50 ppb cause a dramatic increase in heterotrophic activity during the initial 3 to 4 days of a 20 day experiment. Plate counts indicative of total heterotrophic biomass also show a corresponding increase in bacterial numbers. Such stimulation appears to reflect the appearance of increased amounts of labile organic material caused by the toxic effect of copper on the autotrophic component of the marine community. Actually the enhanced heterotrophic response is accomplished by the ascendency of selected bacterial species that have an increased tolerance for copper. Ancillary data on phytoplankton behavior indicate that either death or lysis of primary autotrophs is the important source of the necessary organic material, and that the organic substrates involved are typical of those excreted in dissolved form by a stressed phytoplankton population. In this sequence, heterotrophic bacteria provide a useful function by ensuring a rapid mineralization of stress-derived organic excretions, whose end products provide an abundant source of inorganic nutrients for the development of a secondary phytoplankton regime less susceptible to copper stress.

NODC Accession No.: 75-0529
Organization: University of Georgia
Skidaway Institute of Oceanography
Investigator: M. Takashashi for CEPEX participants
Project title: Controlled Ecosystem Pollution Experiment (CEPEX)

The following summary identifies items submitted to NOAA Environmental Data Service's National Oceanographic Data Center.

Report: CEPEX Progress Report, May 1, 1973 to May 1, 1974—Addendum.

Field Assessment Data—Saanich Inlet:
1) Table of depth, temperature, salinity, NO_3, NO_2, PO_4, and SiO_3.
2) Tables of chlorophyll-a concentration.
3) Tables of concentration of phaeopigments.

Pollutant Transfer and Biological Effects Bibliography

Anderson, J. W., 1973: Uptake and depuration of specific hydrocarbons from oil by the bivalves *Rangia cuneata* and *Crassostrea virginica*, Paper presented at *Workshop on Inputs, Fates, and Effects of Petroleum in the Marine Environment*, Ocean Affairs Board of the National Academy of Sciences, National Resource Council, May 21-25, 1973.

Anderson, J. W., J. M. Neff, B. A. Cox, H. E. Tatem, and G. M. Hightower, 1973: The effects of oil on estuarine animals: Toxicity, uptake and depuration, respiration, Symposium: Effects of Pollutants on the Physiological Ecology of Estuarine Organisms, University of South Carolina, 36 pp., November.

Anderson, J. W., J. M. Neff, B. A. Cox, H. E. Tatem, and G. M. Hightower, 1974: The effects of oil on estuarine animals: Toxicity, uptake and depuration, respiration, in *Pollution and Physiology of Marine Organisms*, J. F. Vernberg and W. B. Vernberg (eds.), Academic Press, N.Y., pp. 285-310.

Anderson, J. W., J. M. Neff, B. A. Cox, H. E. Tatum, and G. M. Hightower, 1974: Characteristics of dispersions and water-soluble extracts of crude and refined oils and their toxicity on estuarine crustaceans and fish, *Mar. Biol.* 27(1):75-88.

Anderson, J. W., J. M. Neff, and S. R. Petrocelli, 1974: Sublethal effects of oil, heavy metals and PCBs on marine animals, in *Survival in Toxic Environments*, M. A. Q. Kahn and J. P. Bederka, Jr. (eds.), Academic Press, N.Y. pp. 83-121.

Anderson, J. W., J. M. Neff, and S. R. Petrocelli, 1974: The mechanisms of survival in toxic environments, Symposium: American Society of Zoologists.

Bidlemen, T. F. and C. E. Olney, 1974: Chlorinated hydrocarbons in the Sargasso Sea atmosphere and surface water, *Science* 183:516-518, February 8.

Brooks, James M., James R. Gormley, and William M. Sackett, 1974: Molecular and isotopic composition of two seep gases from the Gulf of Mexico, *Geophys. Res. Lett.* 1(5): 213-216.

Cox, B. A., and J. W. Anderson, 1973: Some effects of #2 fuel oil on the brown shrimp *Penaeus aztecus, Amer. Zoologist* 13(4):262.

Duce, R. A., J. G. Quinn, and T. L. Wade, 1974: Residence time of non-methane hydrocarbons in the atmosphere, *Mar. Pollut. Bull.* 5(4):59-61.

Farrington, J. W., 1974: Some problems associated with the collection of marine samples and analysis of hydrocarbons, in *Proceedings of Conference/Workshop on Marine Environmental Implication of Offshore Drilling in the Eastern Gulf of Mexico: 1974*, R. E. Smith (ed.), pp. 269-278, University of South Florida, St. Petersburg, Fla. Available from State University System (of Florida) Institute of Oceanography, St. Petersburg, Fla. Also as *Woods Hole Oceanogr. Inst. Tech. Rep.* WHOI-74-23.

Farrington, J. W., J. M. Teal, J. G. Quinn, P. L. Parker, K. Winters, T. L. Wade, and K. Burns, 1974: Analysis of hydrocarbons in marine organisms; results of IDOE intercalibration exercises, in Proceedings of the Marine Pollution Monitoring (Petroleum) Symposium and Workshop, May 13-17, 1974, National Bureau of Standards, Gaithersburg, Md., *NBS Special Publication* 409. Also as *Woods Hole Oceanogr. Insti. Tech. Rep.* WHOI-74-61, 9 pp.

Gormly, J. R., and W. M. Sackett, 1975: Anthropogenic alteration of sedimentary organic carbon, *Geophy. Res. Lett.* 2(5):197-200.

Harvey, George R., 1974: DDT and PCB in the Atlantic, *Oceanus* 18(1):18-23.

Harvey, G. R., 1973: Identification of chlorinated hydrocarbons in and over the Atlantic Ocean, Eastern Analytical Symposium, New York, November 14-16, 1973.

Harvey, George R., 1973: Technical letter: Source of PCBs, *Science* 180(4091):1122.

Harvey, George R., Wm. G. Steinhauer, and John M. Teal, 1973: Polychlorobiphenyls in North Atlantic Ocean water, *Science* 180(4086):643-644.

Harvey, G. R., H. P. Miklas, V. T. Bowen, and W. G. Steinhauer, 1974: Observations on the distribution of chlorinated hydrocarbons in Atlantic Ocean organisms, *J. Mar. Res. 32*(2):103-118.

Harvey, George R. and W. G. Steinhauer, 1974: Atmospheric transport of polychlorobiphenyls to the North Atlantic, *Atmospheric Environment* 8(8):777-782.

Harvey, George R. and W. G. Steinhauer, 1974: Atmospheric transport of polychlorobiphenyls to the North Atlantic, *Atmospheric Environment* 8(8):777-782.

Harvey, G. R., W. G. Steinhauer, and H. P. Miklas, 1974: Decline of PCB Concentrations in North Atlantic Surface Water, *Nature* 252:387-388, November 29.

Medeiros, G. C. and J. W. Farrington, 1974: IDOE-5 intercalibration sample: Results of analysis after sixteen months storage, Proceedings of the Marine Pollution Monitoring (Petroleum) Symposium and Worshop, May 13-17, 1974. *NBS Special Publication* 409. Also as *Woods Hole Oceanogr. Insti. Tech. Rep.* WHOI-74-62.

Pulich, W. M., Jr., K. Winters, and C. Van Baalen, 1974: The effects of a #2 fuel oil and two crude oils on the growth and photosynthesis of microalgae, *Mar. Biol.* 28:87-94.

Roesijadi, G., S. R. Petrocelli, and J. W. Anderson, 1973: The effects of mercuric chloride on the survival and chloride ion regulation of *Petrolisthes armatus* (Crustacea: Porcellanidae). *Amer. Zoologist* 13(4):260.

Roesijadi, G., S. R. Petrocelli, and J. W. Anderson, B. J. Presley, and R. Sims, 1974: Survival and chloride ion regulation of the porcelain crab *Petrolisthes armatus* exposed to mercury, *Mar. Biol.* 27(3):213-217.

Sackett, W. M., 1974: Significance of low-molecular-weight hydrocarbons in Eastern Gulf waters, in *Proceedings of Conference/Workshop on Marine Environmental Implication of Offshore Drilling in the Eastern Gulf of Mexico: 1974* p. 253-267, State University System (of Florida) Institute of Oceanography.

Sackett, W. M. and J. M. Brooks, 1974: Use of low-molecular-weight hydrocarbon concentrations as indicators of marine pollution, in Proceedings of the Marine Pollution Monitoring (Petroleum) Symposium and Workshop, May 13-17, 1974, National Bureau of Standards, Gaithersburg, Md., *NBS Special Publication* 409.

Smith, R. G., Jr., and J. S. Hinkel, 1974: Computerized data reduction for atomic spectrophotometry, *Atomic Absorption Newsletter* 13(5):127-128.

Stickeny, R. R., and D. Miller, 1974: Chemistry and biology of the lower Savannah River, *J. Wat. Poll. Control Fed.* 46(10):2316-2326.

Stickeny, R. R., and S. E. Shumway, 1974: Occurrence of cellulase activity in the stomachs of fishes, *J. Fish. Biol.* 6:779-790.

Stickeny, R. R., G. L. Taylor, and R. W. Heard, III, 1974: Food habits of Georgia estuarine fishes, I. Four species of flounders *(Pleuronectiformes: Bothidae) Fishery Bull.* 72(2):515-525.

Tatem, H. E., and J. W. Anderson, 1973: The toxicity of four oils to *Palaemonetes pugio* (Holthuis) in relation to uptake and retention of specific petroleum hydrocarbons, *Amer. Zoologist* 13(4):261.

Zoller, W. H., E. S. Gladney, and R. A. Duce, 1974: Atmospheric concentrations and sources of trace metals at the South Pole, *Science* 183:198-200, January 18.

In Press

Anderson, J. W., and R. D. Anderson, 1975: Oil bioassays with the american oyster *Crassostrea, virginica* (Gmelin), *Proceedings of the National Shellfisheries Association.*

Anderson, J. W., and B. A. Cox, 1975: An experimental oil spill: The distribution of Aromatic hydrocarbons in the water, sediment and animal tissues within a shrimp pond, *Proceedings of Joint conference on Prevention and Control of Oil Pollution,* San Francisco, March 25-27, 1975.

Anderson, J. W., and J. M. Neff, 1974: Accumulation and release of petroleum hydrocarbons by edible marine animals, International symposium entitled *Recent Advances in the Assessment of the Health Effects of Environmental Pollution,* Paris, June 1974.

Anderson, J. W., and J. M. Neff, 1975: Accumulation, release and distribution of benso(a)pyrene-C^{14} in the clam *Rangia cuneata, Proceedings of Joint Conference on Prevention and Control of Oil Pollutions,* San Francisco, March 25-27, 1975.

Anderson, J. W., and J. M. Neff, 1975: An ultraviolet spectrophotometric methods for the determination of naphthalene and alkylnaphthalnees in the tissues of oil-contaminated marine animals, *Bull. Environ. Contam. Toxicol.*

Anderson, J. W., G. Roesijadi, S. Petrocelli, C. S. Giam, and G. E. Neff, 1975: Blood chloride regulation of juvenile grass shrimp *Palaemonetes pugio* exposed to the polychlorinated biphenyl Aroclor 1254, *Bull. Research Board of Canada.*

Bowen, V. T., and G. R. Harvey, 1973: Levels and effects of PCB in the environment, *World Health Organization, Special Publication.*

Farrington, J. W., and P. A. Meyer, 1974: Hydrocarbons in the marine environment, Chapter 5 in Environmental Organic Chemistry of Oceans, Fjords and Anoxic Basins, G. Eglinton (ed.), Vol. 1 of *Environmental Chemistry, Special Report No.* 35. The Chemical Society, London, U.K.

Environmental Forecasting Program

Long-range and accurate environmental forecasting require knowledge of the processes and mechanisms at work in the oceans and the atmosphere. The Environmental Forecasting Program focuses on projects designed to explain the coupling between the ocean and atmosphere and the influence of the oceans on weather and climate. Experiments and studies include: the Midocean Dynamics Experiment (MODE); the North Pacific Experiment (NORPAX); the International Southern Ocean Study (ISOS); and the Climate—Long-Range Investigation, Mapping, and Prediction (CLIMAP) Study. All of these are being conducted by UNESCO's Intergovernmental Oceanographic Commission.

MODE

Midocean Dynamics Experiment (MODE)

The purpose of MODE is to establish the dynamics and statistics of mesoscale motions in the ocean, their energy source, and their role in the general circulation. The experiment is jointly funded by the National Science Foundation IDOE and U.S. Navy Office of Naval Research (ONR). It consists of coordinated research projects that range from field investigations through theoretical studies.

MODE-0 and MODE-1

MODE began in July 1971. MODE-O included preliminary studies for planning purposes, formulation of theoretical models and schemes for objective analyses, as well as field trials and preliminary field experiments at the MODE site (28°N, 69°40'W) south of Bermuda near the Tropic of Cancer. MODE-1, the main field experiment, was conducted during the spring and summer of 1973 in this region. The MODE-1 program is described in *International Decade of Ocean Exploration Progress Report Volume 3: April 1973 to April 1974.* Results of MODE-1 are being published in scientific journals and are summarized in three reports: *MODE-1 Data Inventory, Instrument Description and Intercomparison Report; Dynamics and the Analysis of MODE-1; and an Atlas of the MODE-1 Data,* which is complete in draft form and will be corrected and recompiled during the next 2 years. The accompanying summaries identify MODE data submitted to NOAA Environmental Data Service's National Oceanographic Data Center.

NODC Accession No.: 75-00133
Organization: Woods Hole Oceanographic Institution
Investigator: A. Voorhis
Grant No.: GX-30220

MODE data: Fixe magnetic tapes containing launch and recovery, temperature, pressure, float and water velocity data collected. April 7 to June 11, 1973.

NODC Accession No.: 75-00724
Organization: Harvard University
Investigator: A. R. Robinson
Grant No.: GX-29033

MODE data: 104 analog copies of XBT traces from Leg 5 of the RV CHAIN cruise 112, June 6 to 13, 1973. (Data are available in digital form.)

NODC Accession No.: 74-00845
Organization: Massachusetts Institute of Technology
Investigator: C. Wunsch
Grant No.: GX-29034

MODE data: One magnetic tape containing 53 files of temperature and pressure. Maximum data points = 7,920 per file. March to July, 1973.

NODC Accession No.: 74-00662
Organization: Yale University
Investigator: T. Rossby
Grant No.: GX-30416

MODE data: One magnetic tape containing positional data from SOFAR floats—4,555 data days (maximum of 6 fixes per day; maximum number of floats = 20). September 28, 1972 to April 30, 1974.

POLYMODE

The United States and the Soviet Union are developing a large-scale midocean dynamics experiment, POLYMODE. It is based on the U.S.S.R. POLYGON program—a continuing series of experiments by Soviet scientists investigating mesoscale phenomena in the Atlantic and Pacific Oceans and in the Arabian Sea—and the MODE program of the United States and the United Kingdom. The POLYMODE experiment is under the direction of a Joint U.S.-U.S.S.R. POLYMODE Organizing Committee, established under the Agreement between the Governments of the United States and the Union of Soviet Socialistic Republics on Cooperation in Studies of the World Ocean.

POLYMODE Field Activities. Scientific objectives of POLYMODE are to:

1) Study the eddy field and eddy-eddy interactions over long time and large space scales;

2) Determine local dynamic balances in a typical region;

3) Determine meridional contributions to eddy transports of momentum, heat, and energy and interactions of eddies with the mean circulation;

4) Study mechanisms that relate to production, transformation, and dissipation of eddy energy;

5) Develop and test numerical models of mesoscale and general oceanic circulation, including mesoscale eddies. These models are especially useful because of their importance in forecasting, process investigation, and coupling to atmospheric models.

The detailed design of the experiment requires quantitative analysis of existing data, formulation of statistical descriptors for the various fields, error estimation through measurement theory, and further numerical modelling studies. Major components of the proposed program are:

1) Current and temperature measurements from moored stations (fig. 4).

2) Density surveys from ships and by other means (such as inverted echo sounders), and

3) Observations of SOFAR floats.

Soviet and U.S. scientists will make current and temperature measurements from moored stations. Soviet scientists will have the main responsibility for density surveys and U.S. scientists for the SOFAR Float Program. Scientists from both countries will participate in the theoretical studies. A preliminary schedule of activities is given in table 1.

U.S. Pre-POLYMODE Activities. Several exploratory efforts are underway in the area identified for POLYMODE, somewhat to the east of the MODE-1 region. One effort is to obtain XBT observations from ships of opportunity crossing the North Atlantic (fig. 5). A pilot current-meter array (Array-1) for POLYMODE-O was set in July-August 1974 to obtain data on low-frequency fluctuations east of the Bermuda Rise along 55-60°W. Array-1 is scheduled to be recovered in April 1975. Five SOFAR floats that were launched during MODE-1 are still being tracked and several new floats have been launched to test a new signaling scheme.

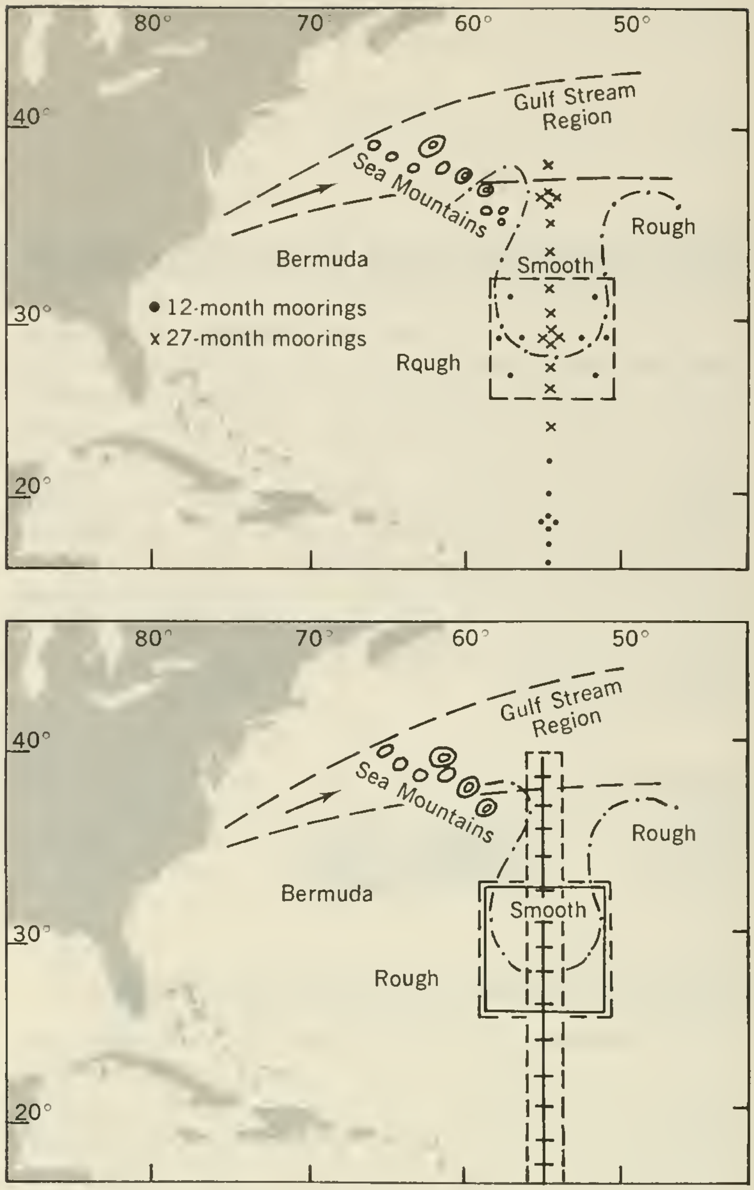


Figure 4.—Proposed POLYMODE mooring pattern (top) and density survey pattern (bottom). U-shaped contour in both figures delineates areas of rough and smooth bottom topography. In bottom diagram, dashed lines enclose mooring pattern of top diagram, solid lines indicate density survey stations and central area.

MODE Bibliography

Baker, D. James, Jr., 1972: The fused quartz deep-sea pressure gauge II, Results of high pressure and deep-sea tests, March-April 1972, *Harvard Reps. Meteorol. Oceanogr.* No. 5.

Baker, D. James, Jr., 1973: The fused quartz deep-sea pressure gauge III, Measurements of pressure fluctuations in the MODE-1 area, August-December 1972, and high pressure calibration, *Harvard Reps. Meteorol. Oceanogr. No. 6.*

Baker, D. James, Jr., Richard B. Wearn, Jr., and Winfield Hill, 1973: Pressure and temperature measurements at the bottom of the Sargasso Sea, *Nature* 245(141):25-26, (MODE Contribution No. 6).

Bennett, David, and J. H. Filloux, 1975: IUGG Quasidynamical Report—Magnetotelluric, deep electrical sounding and resistivity, *J. Geophys. Res.* 13(3):197-202, (MODE Contribution No. 30).

Bretherton, Francis P., and Michael Karweit, 1974: Midocean mesoscale modelling, *Proceedings of Symposium on Numerical Models of Ocean Circulation,* October 17-20, 1972, Durham, N.H., in press, (MODE Contribution No. 23).

Brown, Wendell, Walter Munk, Frad Snodgrass, Harold Möfjeld, and Bernard Zetler, 1975: MODE bottom experiment, *J. Phys. Oceanogr.* 5(1):75-85, (MODE Contribution No. 15).

Bruce, J. G., and Eric Firing, 1974: Temperature measurements in the upper 10 m with modified expendable bathythermograph probes, *J. Geophys. Res.* 79(27):4110-4111, (MODE Contribution No. 21).

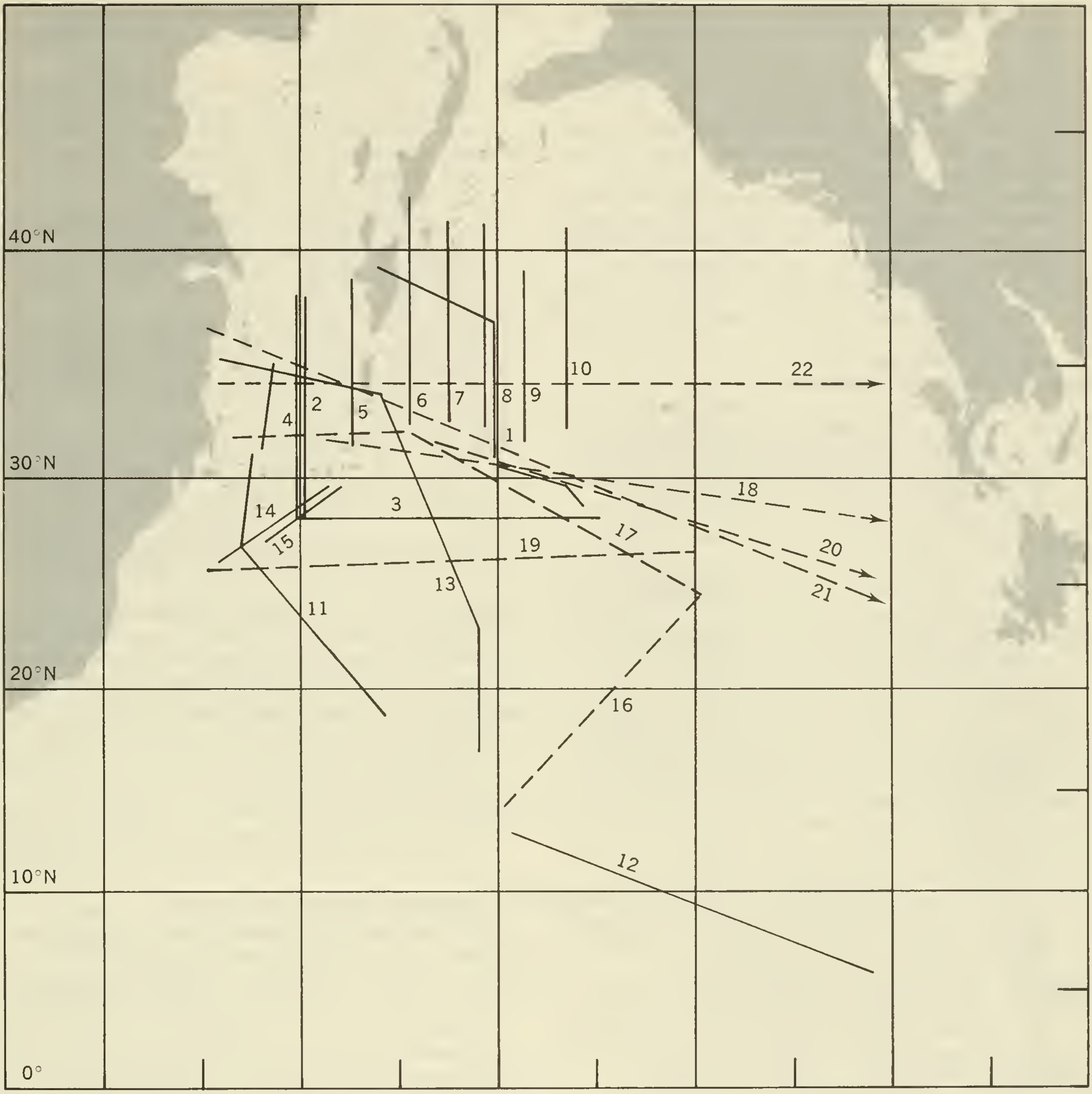


Figure 5.—Locations of pre-POLYMODE XBT sections from ships of opportunity.

Bryan, Kirk, 1973: A model study of abyssal currents in the array-2 area, *MODE Hot Line News,* No. 35, pp. 1-2.

Bryan, Kirk, 1974: Can baroclinically unstable eddies be detected by hydrographic sections? *MODE Hot Line News,* No. 56, pp. 1, 3-4.

Bryden, Harry L., 1974: Geostrophic comparisons using measurements from a moored current and temperature meter, *Nature* 251(5474):409-410, (MODE Contribution No. 10).

Caston, G. F., W. K. Strudwick, and J. C. Swallow, 1974: Neutrally buoyant floats serial nos. 242-265, April 1973, *Inst. Oceanogr. Sci.* (U.K.) *Data Rep.* No. 1.

Caston, G. F., W. K. Strudwick, and J. C. Swallow, 1974: Neutrally buoyant floats serial nos. 266-293, May 1973, *Inst. Oceanogr. Sci.* (U.K.) *Data Rep.* No. 2.

Chhabra, Narender, John Dahlen, and Michele Froidevaux, 1974: Mooring dynamics experiment—determination of

a verified dynamic model of the W.H.O.I. intermediate mooring, *Charles Stark Draper Lab. Rep.* R-823.

Dexter, Steven, John Milliman, and William Schmitz, 1974: Mineral deposition on current meter bearings, *Deep-Sea Res., in press,* (MODE Contribution No. 29).

Dantzler, Lee, Jr., 1974: Dynamic salinity calibration of continuous salinity-temperature-depth data, *Deep-Sea Res.* 21(8):657-682, (MODE Contribution No. 4).

Frankignoul, Claude, 1974: Observed anisotropy of spectral characteristics of internal waves induced by low frequency currents, *J. Phys. Oceanogr.* 4(4):625-634, (MODE Contribution No. 24).

Gould, John, William Schmitz, and Carl Wunsch, 1974: Preliminary field results for a mid-ocean dynamics experiment (MODE-0), *Deep-Sea Res.* 21(11):911-932, (MODE Contribution No. 5).

Hayes, S. P., 1975: The temperature and salinity fine structure of the Mediterranean Water in the Western Atlantic, *Deep-Sea Res.* 22(1):1-11, (MODE Contribution No. 32).

Hayes, S. P., 1975: Preliminary measurements of the time-lagged coherence of vertical temperature profiles, *J. Geophys. Res.* 80(3):307-311. (MODE Contribution No. 31).

Hayes, S. P., T. M. Joyce, R. C. Millard, Jr., 1975: Measurements of vertical fine structure in the Sargasso Sea, *J. Geophys. Res.* 80(3):314-319. Internal Wave Issue, (MODE Contribution No. 28).

Heinmiller, Robert, 1973: Cruise reports, Chain 112, Legs I and II, *Woods Hole Oceanogr. Inst. Ref.* 73-51.

Heinmiller, Robert, 1973: Cruise report, Chain 112, Leg IV, *Woods Hole Oceanogr. Inst. Ref.* 73-50.

Holloway, Gregg, and Myrl Hendershott, 1974: The effect of bottom relief on barotropic eddy fields, *MODE Hot Line News,* No. 65, pp. 1-2.

Huppert, Herbert, and Howard Freeland, 1974: MODE bathymetry, *MODE Hot Line News,* No. 65, pp. 1, 3.

Katz, Eli Joel, 1975: Tow spectra from MODE, *J. Geophys. Res.* 80(9):1163-1167, (MODE Contribution No. 13).

Leaman, Kevin D., and Thomas B. Sanford, 1975: Vertical energy propagation of inertial waves: A vector spectral analysis of velocity profiles, *J. Geophys. Res.* 80(15): 1975-1978, (MODE Contribution No. 19).

McWilliam, James, and Allan R. Robinson, 197 : On the linearized wave properties of the greater MODE region, *Harvard Reps. Meteorol. Oceanogr.* No. 7, Also *MODE Technical Report* 2-T.

MODE Group, 1974: Mid Ocean Dynamics Experiment, 1973, *Science,* in press, (MODE Contribution No. 20).

Muller, Peter, 1974: On the interaction between short internal waves and larger scale motions in the ocean, *Hamburger Geophysikalische Einzelschriftern* 23, (MODE Contribution No. 25).

Muller, Peter, and Dirk J. Olbers, 1975: On the dynamics of internal waves, *J. Geophys. Res.,* September, (MODE Contribution No. 27).

Olbers, Dirk J., 1974: On the energy balance of small-scale internal waves in the deep sea, *Hamburger Geophysikalische Einzelschriften* 24, (MODE Contribution No. 26).

Robinson, Allan R., and James McWilliams, 1974: The baroclinic instability of the open ocean, *J. Phys. Oceanogr.* 4(3):281-294, (MODE Contribution No. 7).

Sanford, Thomas B., 1974: Observations of strong current shears in the deep ocean and some implications on sound rays, *J. Acoustic Soc. Amer.* 56(4):1118-1121, (MODE Contribution No. 17).

Sanford, Thomas B., Robert G. Drever, and John H. Dunlap, 1974: The design and performance of a free-fall electromagnetic velocity profiler (EMVP), *Woods Hole Oceanogr. Inst. Tech. Rep.* WHOI-74-46. Also *MODE Technical Report* 5-T.

Scarlet, Richard I., 1973: STDs in MODE—A grab bag of calibration problems, *Proceedings of Second STD Conference (Supplement),* Plessey Environmental Systems, San Diego, Calif., (MODE Contribution No. 1).

Scarlet, Richard I., 1974: A data-processing method for STD profiles, *Deep-Sea Res.,* in press, (MODE Contribution No. 12).

Scarlet, Richard I., 1975: STDs in MODE—A grab bag of calibration problems: The results, *Proceedings of Third STD Conference (Supplement),* Plessey Environmental Systems, San Diego, Calif., (MODE Contribution No. 22).

Snodgrass, Frank, Wendell Brown, and Walter Munk, 1974: MODE: IGPP measurements of bottom pressure and temperature, *J. Phys. Oceanogr.* 5(1):63-74, (MODE Contribution No. 14).

Swallow, John, 1974: R.R.S. Discovery Cruise 53, April-June 1973, *NIO Cruise Report* No. 58, National Institute of Oceanography, (U.K.). Also *MODE Technical Report* 3-T.

Swallow, John, M. S. McCartney, and R. W. Millard, 1974: The minimode float tracking system, *Deep-Sea Res.* 21(7):573-595, (MODE Contribution No. 11).

Voorhis, Arthur D., and Raymond R. Benoit, 1974: MODE SOFAR float in-situ data summary, *Woods Hole Oceanogr. Inst. Tech. Rep.* WHOI-74-37. Also *MODE Technical Report* 6-T.

Zetler, Bernard, Walter Munk, Harold Mofjeld, Wendel Brown, and Florence Dormer, 1974: MODE tides, *J. Phys. Oceanogr.,* in press, (MODE Contribution No. 16).

Zenk, Walter, and Eli Joel Katz, 1975: On the stationarity of high wavenumber spectra, *J. Geophys. Res.,* in press, (MODE Contribution No. 18).

North Pacific Experiment (NORPAX)

The long-term objective of NORPAX is to understand fluctuations in the upper layers of the North Pacific Ocean with time scales of months to years and space scale in excess of 1,000 kilometers, and the relation of these fluctuations to the overlying and adjoining atmosphere. Achievement of this goal should lead to improved prediction of weather and climate for the northeast Pacific Ocean and North America. NORPAX is jointly sponsored by IDOE and the Office of Naval Research. Principal investigators and projects are listed in table 6. Immediate objectives of NORPAX are to:

1) Describe the configuration and evolution of observed sea surface thermal anomalies.

2) Determine the locations and magnitudes of heat fluxes across the sea surface and how they vary with time.

3) Obtain a quantitative explanation for the evolution of the mixed layer.

4) Determine to what extent fluctuations in momentum flux from the atmosphere affect advection of oceanic heat storage and ocean/atmosphere heat flux.

5) Determine optimum methods for quantitative monitoring of fluxes between the ocean and atmosphere system.

During the past year, analysis of data from POLE—the first process-oriented field study project conducted north of Hawaii (35°N, 155°W) during January and February 1974—was continued.

El Niño Watch

Systematic scientific observations have never been made during an El Niño in waters off Peru. Predictive indices based on the Southern Oscillation (a zonal atmospheric cell linking the eastern and western equatorial Pacific) have a lead time of approximately 6 to 12 months. Indications in early 1975 were that another El Niño might occur. This led to the NORPAX expedition "El Niño Watch"—two cruises of about 5 weeks duration (February to April 1975) between latitudes 2°N and 15°S and from the west coast of South America to longitude 97°W (fig. 6). Observations of meteorological and oceanographic parameters, including nutrients, were made to determine the source of El Niño water.

The accompanying summaries identify NORPAX data submitted to NOAA Environmental Data Service's National Oceanographic Data Center.

NODC Accession No.: 75-0530
Organization: Scripps Institution of Oceanography
Investigator: R. T. Wert, NORPAX Data Manager

NORPAX data: One magnetic tape containing observations from 23 bumble bee buoys (at 1-hour intervals). Parameters are:

1) air temperature
2) wind speed and direction
3) wind transport
4) barometric pressure
5) sea temperature at a maximum of 12 depths
6) pressures at two depths
7) solar radiation
8) mooring line tension

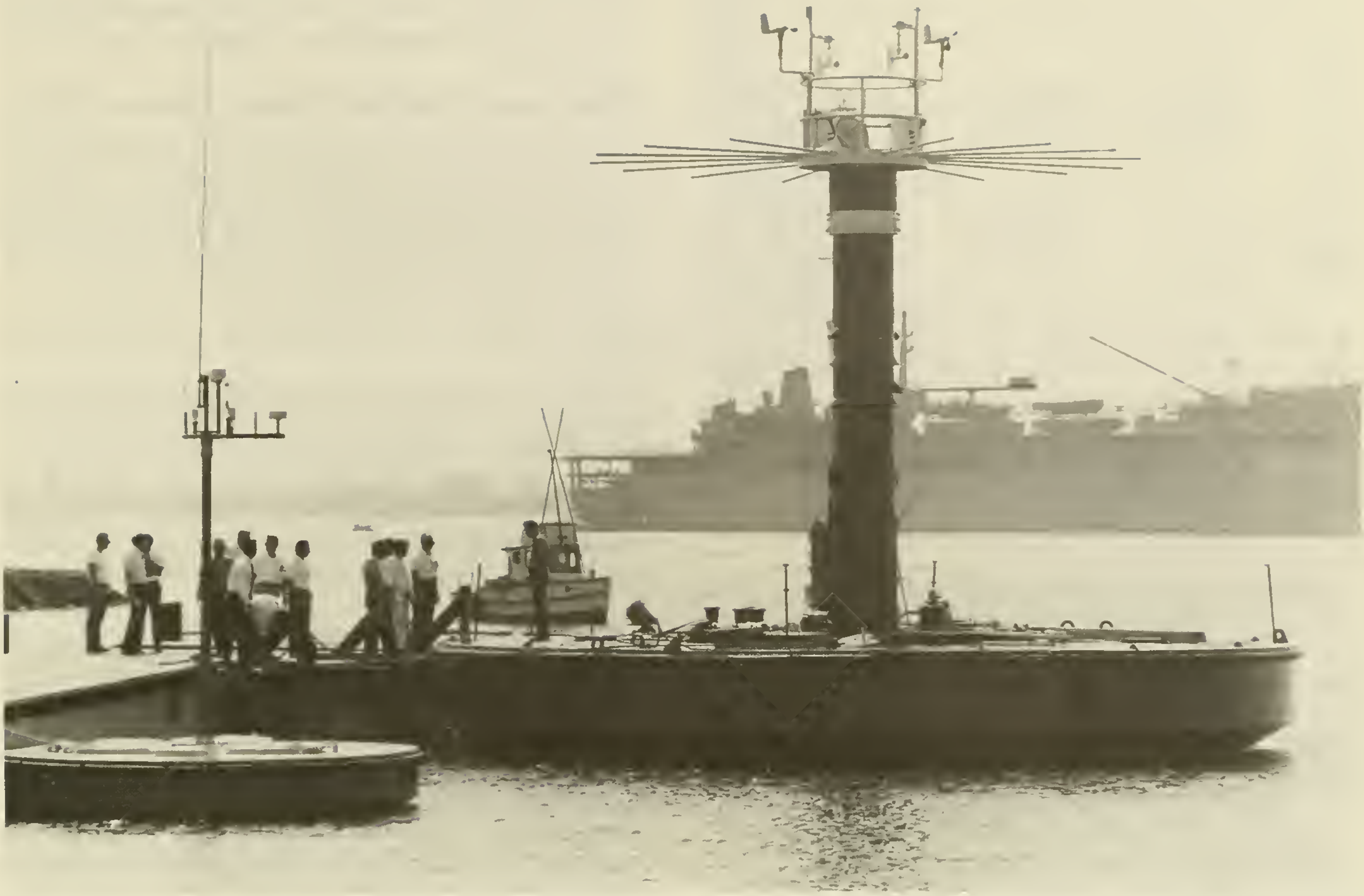
Data were collected from 6 buoys during May 1964 to February 1967 and from 17 buoys during February 1968 to February 1973.

Table 6.—U.S.-funded institutions, investigators, and projects in NORPAX program

Organization	Investigator	Project title
University of Alaska	T. C. Royer	Large-Scale Air-Sea Interaction in the Gulf of Alaska and Bering Sea
University of British Columbia	M. Miyake	Air-Sea Interaction Study With Aircraft
University of California Los Angeles	J. Bjerknes	Large-Scale Ocean-Atmosphere Interaction
University of California Scripps Institution of Oceanography	T. P. Barnett	Temperature Velocity Structure Study
	R. L. Bernstein	Objective Analysis of Ship's Injection Temperatures
	R. L. Bernstein W. B. White	Space/Time Variability of Subsurface Thermal Structure and Fluxes of Heat and Momentum
	R. E. Davis	Radio Beacon Drift Buoys
	R. E. Davis R. A. Knox	Analysis of POLE Data
	M. C. Hendershott	A Model Study of Large-Scale Ocean-Atmospheric Interaction

Table 6.—U.S.-funded institutions, investigators, and projects in NORPAX program—continued

Organization	Investigator	Project title
	K. E. Kenyon	Large-Scale Dynamics of the Upper Ocean
	G. J. McNally	Satellite Tracked Drifting Buoys
	J. Namias C. K. Stidd	Large-Scale and Long-Term Air-Sea Interaction Over the Pacific and Remote Weather and Climate Influences
	R. H. Stewart	Remote Sensing of Winds
	R. T. Wert	NORPAX Data Program
	R. T. Wert	Process Mechanical BTs
	R. T. Wert	NORPAX Administration and Travel
	W. B. White	Annual Variability in Large-Scale Baroclinic Transport of the North Pacific and Its Relation to Thermal Anomalies in Upper Ocean
University of California San Diego	C. A. Friehe	Measurement of Surface Fluxes of Heat, Water Vapor, and Momentum From Aircraft and Merchant Ships
University of Hawaii Institute of Geophysics	M. J. Vitousek	Line Islands Monitoring
	K. Wyrtki	Interaction of Circulation, Sea Level, Heat Storage, and Winds Over the Pacific Ocean
	K. Wyrtki	El Niño Watch
California Institute of Technology Jet Propulsion Laboratory	M. T. Chahine	Remote Sounding of Temperature of the Ocean Surface in Cloudy Atmosphere
University of Michigan	J. C. K. Huang	Numerical Simulation of Climatic Fluctuations in the Pacific
National Marine Fisheries Service, NOAA	D. R. McLain T. Saur	Time Series XBT Sections
Naval Fleet Numerical Weather Central	C. R. Ward	Continuance of Ships of Opportunity Program
Naval Postgraduate School	R. L. Haney	Numerical Simulation of Coupled North Pacific Ocean-Atmospheric System
Oregon State University	P. P. Niiler	Examination of the Validity of the Local Theories of the Seasonal Thermocline
	C. Paulson	Ocean Mixed-Layer Structure
	W. H. Quinn	Large-Scale and Long-Term Fluctuations in the Ocean and Atmosphere Over Lower Latitudes of the Pacific and Their Consequences
Stanford University	A. M. Peterson G. L. Tyler	Radar Studies of Sea and Decametric Radio-Wave Observations of the North Pacific
Texas A & M University	A. D. Kirwan	A Study of Large-Scale Ocean-Atmospheric Coupling Through Use of Free-Drifting Buoys
University of Tokyo	H. Solomon	The Role of Western Boundary Currents in Large-Scale Air-Sea Interaction in the North Pacific
University of Washington	B. A. Taft	Kuroshio Index; History and Recent Observations
Woods Hole Oceanographic Institution	P. M. Saunders	Evaluation of Performance of Near-Surface Drifters



The buoy DANA ready for sea at Scripps Marine Facility. Buoy was moored 20 miles off San Diego in 1973 and 1974 and served as a test platform for NORPAX.

NODC Accession No.: 74-00748
Organization: NOAA National Marine Fisheries Service, La Jolla

Investigator: J. F. T. Saur
Grant No.: AG-256

NORPAX data: 1460 digitized XBT drops from the Pacific Ships of Opportunity Program during the period April 1973 to July 1974.

NORPAX Bibliography

Anonymous, 1973: Deep moored instrument station cruise report, NORPAX, *Scripps Inst. Oceanogr. Ref. Series* 73-13, 26 pp.

Anonymous, (no date): North Pacific study—physical data report, NORPAX, *SIO Ref. Series* 73-26, 121 pp.

Huang, J. C. K., 1972: Recent decade variation in the California current system, *J. Phys. Oceanog.* 2(4):382-390.

Namias, Jerome, 1974: Suggestions for research leading to the long-range precipitation forecasting for the tropics, *Amer. Meteorol. Soc.*, 4 pp.

Barnett, T. P., and R. L. Bernstein, 1974: Space/time scales of fluctuations of ocean temperature, NORPAX, *SIO Ref. Series* 74-23, Univ. Calif., 13 pp.

Bernstein, R. L., and W. B. White, 1974: Time and length scale of baroclinic eddies in the central North Pacific Ocean, *J. Phys. Oceanogr.* 4(4):613-624.

Bjerknes, J., 1974: Atmospheric teleconnections from the equatorial Pacific during 1963-67, Final Report, National Science Foundation Grant GA 27754, 38 pp.

Bjerknes, J., 1974: Preliminary study of the atmospheric circulations during the period preceding the 1972-73 El Niño, A NORPAX contribution, Department of Meteorology, UCLA.

Bjerknes, J., (no date): Rhythmic variations of the Hadley circulation over the Pacific during 1963-67, *NORPAX Tech. Rep.*, September 1972 to August 1973, 24 pp.

Collins, C. A., W. S. Wilson, J. Carlmark, and T. P. Barnett, 1973: The North Pacific experiment probes weather phenomenon, MTS Journal, pp. 10-13.

Huang, Joseph Chi Kan, 1973: A multi-layer, nonlinear regional dynamic model of the North Pacific Ocean, NORPAX, *SIO Ref. Series* 73-23, Univ. Calif., 45 pp.

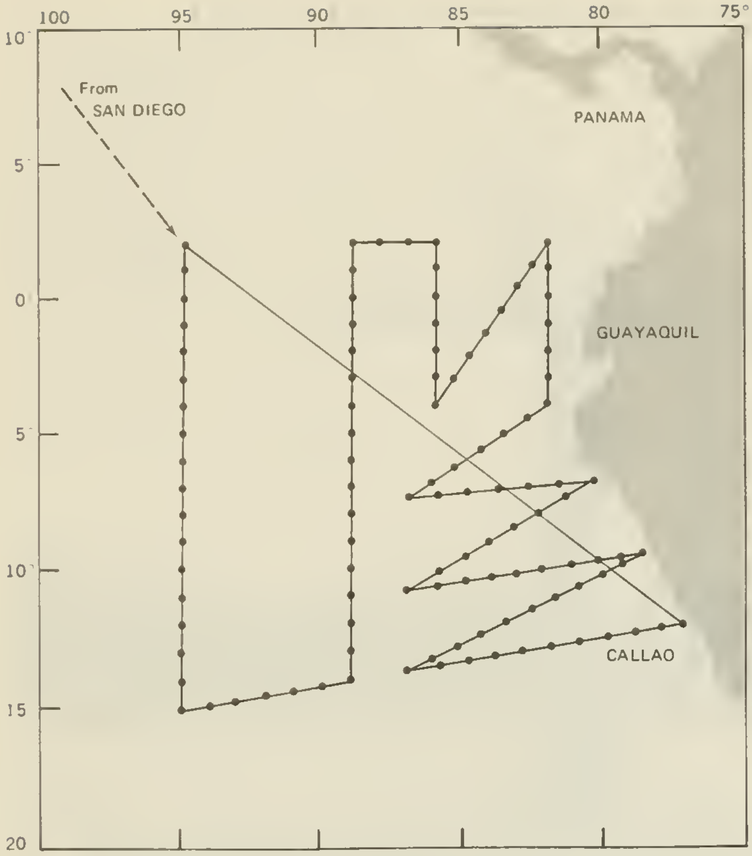


Figure 6.—El Niño Watch cruise tracks.

Barnett, T. P., 1974: The North Pacific Experiment: A study of large-scale ocean and atmospheric fluctuations in the Pacific, WMO Reports on Marine Affairs #7, Means of Acquisition and Communication of Ocean Data-II, Proc. WMO Tech. Conf., Tokyo, Oct. 2-9, 1972, pp. 333-344.

Namias, Jerome, 1974: Longevity of a coupled air-sea-continent system, *Mon. Wea. Rev.* 102(9):638-648.

Namias, Jerome, 1972: Influence of northern hemisphere general circulation on drought in Northeast Brazil, *Tellus* 24(4):336-343.

Namias, Jerome 1972: Experiments in objectively predicting some atmospheric and oceanic variables for the winter of 1971-1972, *J. Appl. Meteorol.* 11(8):1164-1174.

Peloquin, R. A., 973: A fixed gantry for handling data buoys at sea, NORPAX, *SIO Ref. Series* 73-32, Univ. Calif., 60 pp.

Plutchak, D. A., and Troxler, F. D., 1973: A preliminary analysis of errors in wind measurements from ocean data buoys, *NORPAX Technical Report* R-73-005, General Dynamics Corp. Electronics Division, San Diego, Calif.

Quinn, William H., 1974: Monitoring and predicting El Niño invasions, *J. Appl. Meteorol.* 13(7):825-830.

Stidd, C. K., 1973: Estimating the precipitation climate, *Water Resources Res.* 9(5):1235-1241.

Stidd, C. K., 1974: Ship Drift Components: means and standard deviations, NORPAX *SIO Reference Series* 74-33, 57 pp.

Tubbs, Anthony M., 1972: Summer thunderstorms over southern California, *Mon. Wea.* Rev. 100(11):799-807.

White, W. B., and T. P. Barnett, 1972: A servo mechanism in the ocean/atmosphere system of the mid-latitude North Pacific, *J. Phys. Oceanogr.* 2(4):372-381.

White, W. B., and M. W. Evans, 1972: Synoptic time and length scale of motion in the North equatorial current system of the Pacific Ocean, *J. Geophys. Res.* 77(30): 5971-5980.

International Southern Ocean Studies (ISOS)

These studies focus on dynamic processes in the Southern Ocean and their relation to oceanic and atmospheric circulation patterns. Projects include studies of large-scale, time-dependent dynamics of the Circumpolar Current and Polar Front. Future studies may include the processes of bottom water formation and their variability. ISOS projects are listed in table 7.

F DRAKE (First Dynamic Response and Kinematics Experiment)

F DRAKE described selected distributions of properties and regional phenomena in the Drake Passage and Scotia Sea region. This effort was directed to: delineating the path, baroclinic structure, and property distributions of the Circumpolar Current; determining its spatial relation to the Polar Front in the Drake Passage and western Scotia Sea; and preparing a detailed description of the Polar Front Zone at a selected location.

Time Series of Velocity, Temperature, and Pressure at Drake Passage. Three types of arrays containing internally recording instruments were deployed in the Drake Passage during the January to March 1975 field operation (fig. 7).

1) An array of 10 current and temperature recorders. This array was used to obtain a 1-year time series of horizontal velocity (V) and temperature (T) in the deep and bottom water. Of primary interest was the estimates of amplitudes of motions and temperature changes having periods up to weeks, spatial coherence as a function of frequency, the "mean" flow, and the degree of meridional shifting of the flow in the passage.

2) A short-term array of 12 instruments. This array was

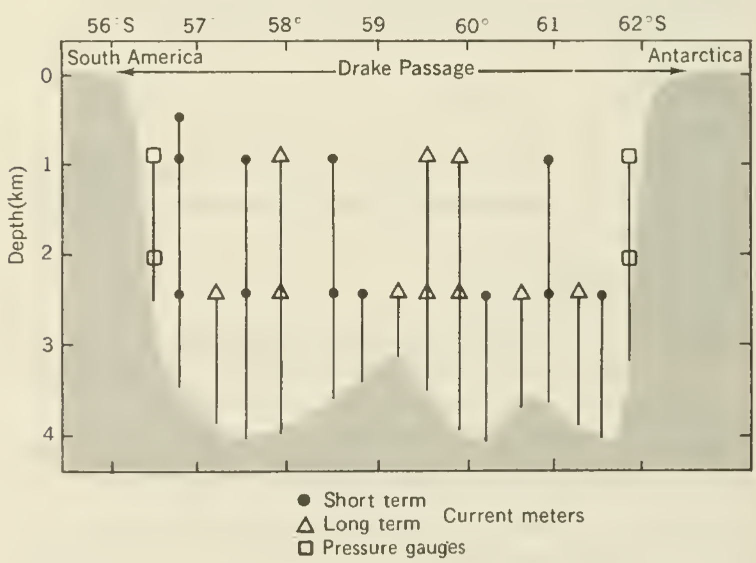


Figure 7.—Schematic of instrument arrays in Drake Passage.

Table 7.—U.S. institutions, investigators, and projects in ISOS program

Organization	Investigator	Project title
Columbia University, Lamont-Doherty Geological Observatory	A. Gordon	Planning Activities and Oceanographic Atlas
	A. Gordon S. Jacobs	Investigation of Physical Oceanography of the Northwest Scotia Sea and Falkland Plateau
NOAA Data Buoy Office	J. Winchester	A Pilot Drifting Buoy Experiment in the Southern Ocean
Oregon State University	V. T. Neal	International Coordination
	V. T. Neal H. Crew	Study of Thermohaline Processes under Antarctic Sea Ice in Winter
	R. D. Pillsbury R. L. Smith	Study of Long-term Variability of the Antarctic Circumpolar Current in the Drake Passage
Texas A & M University	A. D. Kirwan	Interpretation of Drifter Observations
	W. D. Nowlin	Central Administrative Coordination and Planning
	W. D. Nowlin P. K. Park	Chemical and Physical Oceanography of the Antarctic Circumpolar Current and Frontal Zones: I. Observations in the Drake Passage and Scotia Sea
	P. K. Park	Antarctic Oceanography in the Drake Passage and Scotia Sea aboard ARA Islas Orcadas, 1975
University of Southern California	T. Maxworthy	Laboratory Modelling Studies of Antarctic Circumpolar Current
University of Washington	D. J. Baker	Coordination of Monitoring Activities and Liaison with the Polar Experiment of the Global Atmospheric Research Program
	D. J. Baker	1975 Theoretical Workshops
	D. J. Baker	Transport Measurements of the Antarctic Circumpolar Current and Analysis of Existing Tidal and Meteorological Data
Woods Hole Oceanographic Institution	J. R. Luyten	A Planning Program for the Working Group on Theoretical and Special Process Studies
	T. Joyce	Dynamical Observations at the Antarctic Polar Front

implanted during the deployment cruise to measure V and T. The data will supplement those from the long-term array and will be useful in estimating the strength and coherence of short-period fluctuations. This data will provide the only time series available for study during 1975 and for planning the 1976 field effort.

3) Four internally recording pressure gauges. Two were placed at the northern end and two at the southern end of Drake Passage to remain for 1 year. The sensors were at depths of 100 to 200 m on the continental shelves. If the instruments perform to within their stated accuracy of $\pm$ 1cm of water, these measurements should give useful estimates of cross-stream pressure changes—which are observed to have amplitudes at long periods of as much as 20 cm.

Measurements of Physical and Chemical Properties in Sections Across Drake Passage. A hydrographic section of physical and chemical measurements was made across Drake Passage to examine the baroclinicity before current and temperature recording arrays were deployed. Special attention was given to bathymetry before and during deployment. These measurements were supplemented by others during deployment. A second set of measurements was obtained when the short-term array was retrieved.

Based on existing oceanographic information, the flow through Drake Passage seems to have two regions of large baroclinic shear relative to that in the water between these "cores." The first hydrographic section determined the location of these cores so that the current and temperature arrays could be properly deployed. The second hydrographic section permitted detailed sampling of features observed during the first section. The second section also was compared with the first to see whether large changes in the position of the baroclinic structure occur.

Deep stations were made within the Bransfield Strait, which

is believed to be a possible area of active deep convection and water formation. Additional stations were occupied south of the South Scotia Ridge as part of the ISLAS ORCADAS hydrographic section, which crossed the Circumpolar Current at 58°W.

Description of Circumpolar Current and Polar Front downstream from Drake Passage to North Scotia Ridge/Falkland Plateau. Based on available data, e.g., the depth of the salinity maximum core or relatively dynamic topography, the Circumpolar Current may consist of two "cores" of large baroclinic pressure gradients. The northernmost seems to continue downstream from Drake Passage along the southern flank of the North Scotia Ridge to about 45°W where it crosses this Ridge.

The southern core seems to meander downstream, probably influenced by bottom topography, and perhaps divides or becomes diffused within the central Scotia Sea. Using two vessels, a series of oceanographic sections was occupied across these cores and the Polar Front, from upstream of Drake Passage eastward to about 43°W. Several of these sections extended far enough south to cross all of the principal baroclinic flow and perhaps to reach the Weddell-Scotia Confluence. These longer sections were intended to ascertain the spatial extent and structure of the apparent double axis of the Circumpolar Current in the western Scotia Sea.

Principal objectives of this subprogram were to describe the spatial distributions of mass and properties and the relationship of the baroclinic current structure to the Polar Front in the Scotia Sea. Knowledge about this relationship within the Antarctic Circumpolar Current system may make it possible to trace or monitor spatial configurations of the Current from data obtained only in the upper layer structure (such as using AXBTs from aircraft). If there is a unique relationship between the current axis and polar front, then detailed information on the wavelike form and possible meandering, or even eddy formation, of the northern current axis might be obtained without detailed hydrographic surveys.

Detailed descriptions of Polar Frontal Zone. The Polar Front makes a large meander pattern across the North Scotia Ridge between 46° to 50°W. The most commonly observed position is over a deep passage at 48° to 49°W. This feature is unique in that at no other region around Antartica does the Front take on a north-south orientation, or even reverse direction (from SSE to NNW). The integrity of the front in this region may be severely diminished and the area may be a major source of Antarctic Intermediate Water. Hydrographic survey coverage described the position and structure of the Polar Front in this unusual region.

STD data taken by Gordon in the Polar Frontal Zone indicate considerable vertical structure in the upper waters. Examination of this structure and the associated temperature-salinity relationships indicate considerable interleaving of water masses in this zone. These structures were mapped over a limited area, using XBT's and STD's from two vessels.

Future Activities.

In 1976, the long-term arrays in Drake Passage will be reset along with special deep (4000 m) pressure gauges. At this time, several satellite-tracked drifting buoys will be launched. Also, mixing processes at the Polar Front will be investigated using a high-resolution CTD and Swallow floats.

Climate: Long-Range Investigation, Mapping, and Prediction (CLIMAP) Study

CLIMAP research focuses on describing and explaining climatic changes over the last million years. Accurate descriptions of climatic change over the time scale will improve the CLIMAP scientists' understanding of transitions between what are considered to be the two stable states of global climate—the ice age and temperate period. These studies will also increase knowledge about mechanisms of climatic change by comparing global climatic descriptions derived from sample analyses and those produced by computer models.

The CLIMAP Study is unique in that analyses of deep-sea sediments are used as the primary source of data. Characteristics that make these sediments good indicators of past climatic conditions are:

1) *Their global extent.* Studies of other materials—ice cores, glacial moraine deposits, tree rings, and lake and bog sediments—are geographically restricted. The global extent of deep-sea sediments also adds to their value as climatic indicators because of the global exchange of latent and sensible heat between the ocean and the atmosphere, which plays a dominant role in climate.

2) *Their relatively constant rate of accumulation.* The continuous and relatively constant rate of sediment accumulation imparts a continuity to the climatic record in sediments. Some sediment records are unbroken for many thousands of years, whereas other records, such as those from tree rings, provide only a record of the continental atmosphere at selected sites for periods extending back 6,000 years. Continuous deep-sea sediment records of the past 100,000 to 1 million years are the standard against which data from ice cores, pollen samples, and moraine deposits are calibrated, and by which terrestrial climatic records are seen in true perspective.

3) *Their multivariate character.* Deep-sea sediments contain many indicators of past environmental conditions. Interrelationships among these indicators make possible a wide range of correlative studies. For example, scores of species of plankton, each responding to different combinations of environmental factors in surface waters, and many benthonic species that reflect conditions at the sea bottom, are preserved as microfossils in deep-sea sediments. By applying appropriate counting techniques and multivariate transfer functions, quantitative estimates can be made of water conditions during the life of these organisms. This information is then used in numerical models of paleoclimates. Oxygen isotope ratios preserved in microfossil skeletons reflect changes in the global ice column. Mineral and chemical properties of the sediments are used to determine chemical and physical properties of the water and wind and current patterns.

CLIMAP research is advancing along three distinct lines or strategies, each formalized as a program seeking answers to specific questions.

Global Climate Reconstruction Program

This program is assembling synoptic arrays of data to reconstruct past changes and near equilibrium states of the global climate. Limitations in the models and within the stratigraphic records will determine the number of reconstructions. Time periods to be mapped are selected to solve specific problems, such as "What were the global climatic characteristics just prior to the onset of the ice age?" Data from the reconstructed climates will be used to improve numerical models of climate and to test and evaluate the accuracy of computer models.

Regional Climate Dynamics Program

Objectives of this program are to identify regions and specific mechanisms that play critical or controlling roles in climatic change. For example, changes in global albedo and formation of deep ocean waters are important in high latitudes. The flux of latent and sensible heat to the atmosphere is significant in lower latitudes. All parts of the global climatic system must be considered, including the interplay between active regions and between active and stable regions. The role of different phases of fluid systems that enter into climatic change will be studied, as will details of the continental atmosphere in low and middle latitudes, the extent of sea and land ice, and the temperature of surface and bottom ocean waters.

Climatic Time-Series Program

This program generates time-series of variables considered to be significant indices of climate. The time-series are analyzed for periodicities. They provide a basis for identifying different climatic regimes and for making correlations in the stratigraphic records. For example, qualitative analyses of fluctuations in alpine glaciers have given new insight into climatic change during the Holocene. Quantitative analyses, using spectral and filter techniques, have yielded oxygen isotope curves that reflect changing global ice volume and selected biotic indices that reflect changes in water-mass boundaries (fig. 8).

Time-series data have been fertile sources of theories on the fundamental causes of climatic change. The 2,500-year cycle of little ice ages, for example, has been interpreted as evidence of a sun and climate link, and the 100,000-year climatic cycle that is evident in many records of the past half-million years has been interpreted as an effect of changes in the Earth's solar orbit. Although neither concept has led to a tested theory of climatic change, the search for mechanisms to explain well-documented cycles will continue.

Summary of Accomplishments

Accomplishments of CLIMAP include the following:

1. Formation of a interdisciplinary team to study climatic change during the last million years.

2. Development of techniques to estimate past sea-surface temperatures in all oceans, using four selected faunal and floral groups.

3. Preparation of a global map of sea-surface temperature 18,000 years B.P. (before present). See figure 9.

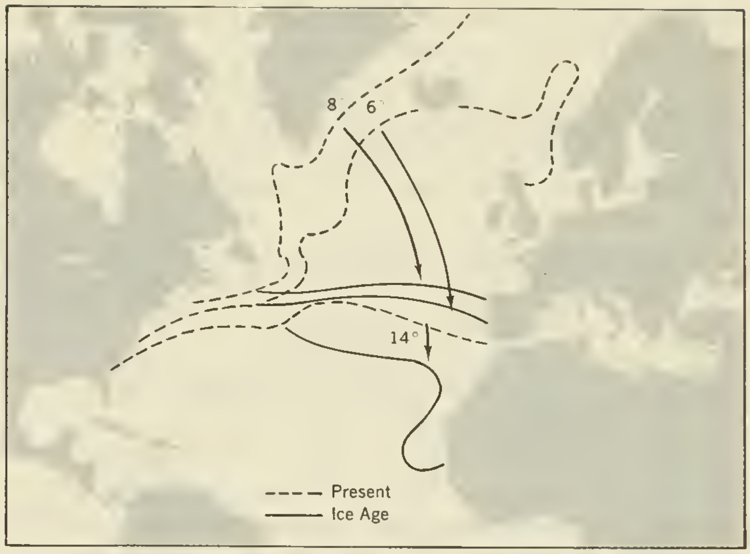


Figure 8.—Southward shift of cold Arctic water 18,000 years also suggests there was a more southerly flow of warm Gulf Stream waters across the Atlantic Ocean.

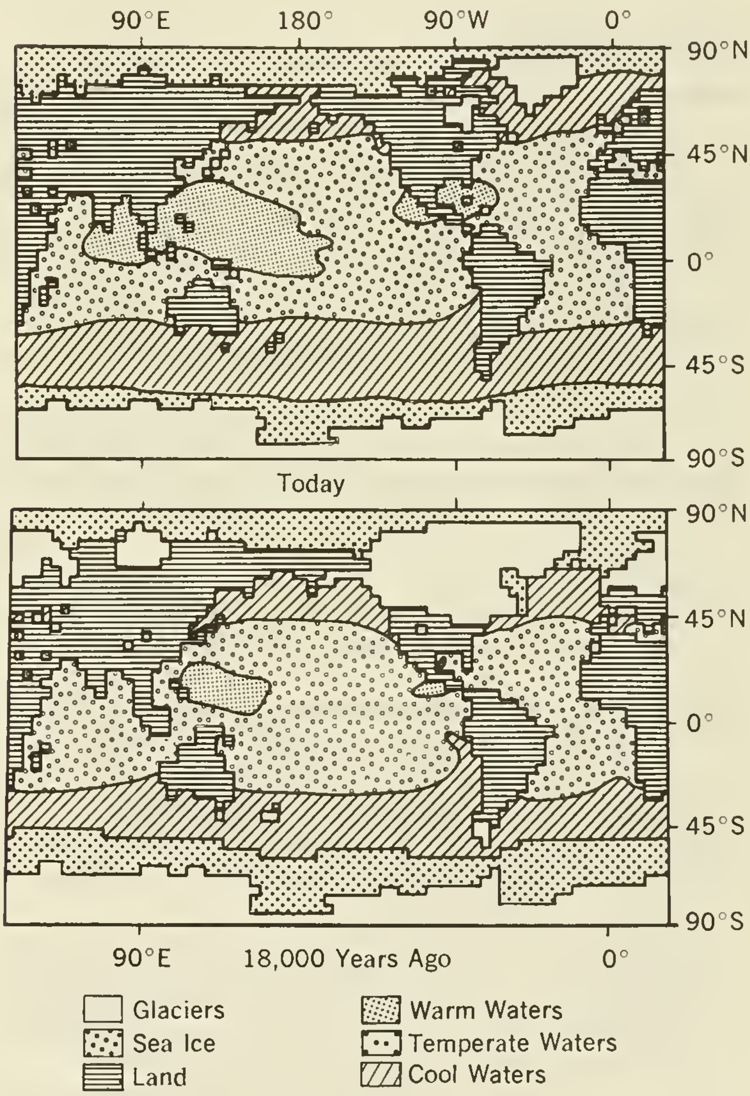


Figure 9.—Comparison of surface features 18,000 years ago and today.

4. Formation of a procedure for precise global stratigraphic correlations based on the O^{18}/O^{16} ratio.

5. Determination of the extent and elevations of ice sheets for the Northern Hemisphere summer 18,000 years B.P.

6. Establishment of first-order chronology for ice-ages of the past million years.

7. Numerical simulation of atmospheric circulation 18,000 years B.P. (in cooperation with the Advanced Research Projects Agency's Climate-Dynamics Program).

8. Compilation of detailed climatic narratives for many parts of the world ocean during the past 150,000 years.

9. Documentation of many details of the climatic narrative for the past 14,000 years, especially the 2,500-year-cycle of little ice ages shown by alpine-glacier fluctuations and the geographic pattern of deglaciation shown by North American vegetation records and by North Atlantic deep-sea core analyses.

10. Establishment of working relationships with scientists who are formulating numerical models of climate, agriculture, and the marine ecosystem.

CLIMAP Bibliography

Andrews, J. T., S. Funder, C. Hjort, and J. Imbrie, 1974: Comparison of the glacial chronology of eastern Baffin Island, East Greenland, and the Camp Century accumulation record. *Geology* 2(7):355-358.

Bender, M. L., F. T. Taylor, and R. K. Matthews, 1973: Helium-uranim dating of corals from Middle Pleistocene Barbados reef tracts, *Quaternary Res.* 3(1):142-146.

Björklund, K. R., 1974: The seasonal occurrence and depth zonation of radiolarians in Korsfjorden, Western Norway, *Sarsia* 56:13-42.

Burckle, L. H., 1972. Diatom evidence bearing on the Holocene in the South Atlantic, *Quaternary Res.* 2:323-326.

Denton, G. H., and W. Karién, 1973: Holocene climatic variations—their pattern and possible cause, *Quaternary Res.* 3(2):155-205.

Denton, G. H., and W. Karlén, 1973: Lichenometry: Its application to Holocene moraine studies in southern Alaska and Swedish Lapland, *Arctic and Alpine Res.* 5(4): 347-372.

Denton, George H., 1974: Quaternary glaciations of the White River Valley, Alaska, with a regional synthesis for the Northern St. Elias Mountains, Alaska and Yukon Territory, *Geol. Soc. Amer. Bull.* 85(6):871-892.

Denton, George H., and W. Karlén, 1975: Holocene glacier variations Sarek National Park, Swedish Lapland, in *Geografiska Annaler*, 70 pp.

Diester-Haas, L., H. J. Schrader, and J. Thiede, 1973: Sedimentological and paleoclimatological investigations of two pelagic ooze cores off Cape Barbas, North-west Africa, *"Meteor" Forsch.* Ergebn., C16, 19-66, Berline-Stuttgart (in association with CLIMAP).

Dymond, Jack, Pierre E. Biscaye, and Robert Rex, 1974: Eolian origin of mica in Hawaiian soils, *Geol. Soc. Amer. Bull.* 85(1):37-40.

Gardner, J. V., 1975: Later Pleistocene carbonate dissolution cycles in the eastern equatorial Atlantic, in Dissolution of deep-sea carbonates, W. V. Sliter, A. W. H. Bé, and W. H. Berger (eds.), *Cushman Foundation for Foraminiferal Research, Spec. Pub.* no. 13, 142-150.

Gates, W. L., and J. Imbrie, 1975: Climatic change, in *Meteorology 1971-1975, Quadrennial Report to IUGG*, P. M. Bell (ed.).

Imbrie, J., van Donk, J., and Kipp, N. G. 1973: Paleoclimatic investigation of a Late Pleistocene Caribbean deep-sea core: Comparison of isotopic and faunal methods, *Quaternary Res.* 3(1):10-38.

Imbrie, J., W. Broecker, and others. 1975: A survey of past climates, Appendix A, in National Academy of Sciences "Understanding Climatic Change: A Program for Action," Panel on Climatic Variation, U.S. Committee for GARP, NAS, Washington, D.C.

Karlén, W., 1973: Holocene glacier and climatic variations, Kebnekaise Mountains, Swedish Lapland, *Geografiska Annaler* 55A, #1, 29-63.

Kukla, G. J., and A. Kočí, 1972: End of the last interglacial in the loess record, *Quaternary Res.* 2(3):374-383.

Kukla, G. J., and H. J. Kukla, 1972: Insolation regime of interglacials, *Quaternary Res.* (3):412-424.

Kukla, G. J., and R. K. Matthews, 1972: When will the present interglacial end? *Science* 178(4057):190-191.

Kukla, G. J., R. K. Matthews, and J. M. Mitchell, Jr., 1972: Guest editorial: The end of the present interglacial, *Quaternary Res.* 2(3):261-269.

Kukla, George J., and H. J. Kukla, 1974: Increased surface albedo in the northern hemisphere, *Science* 183:709-714.

Kukla, G. J., 1975: Loess stratigraphy of Central Europe, in *After the Australopithecines*, K. W. Butzer and G. L. Issac (eds.), Mouton, The Hague.

Kulm, L. D., Johanna M. Resig, Ted C. Moore, Jr., and Victor J. Rosato, 1974: Transfer of Nazca Ridge pelagic sediments to the Peru continental margin, *Geol. Soc. Amer. Bull.* 85(5):769-780.

Luz, B., 1973: Stratigraphic and paleoclimatic analysis of Late Pleistocene tropical southeast Pacific cores (with an Appendix by N. J. Shackleton), *Quaternary Res.* 3(1): 56-72.

Luz, B., and N. J. Shackleton, 1975: $CaCO_3$ solution in the tropical east Pacific during the past 130,000 years, in Dissolution of deep-sea carbonates, W. V. Sliter, A. W. H. Bé, and W. H. Berger (eds.), *Cushman Foundation for Foraminiferal Research Spec. Pub.* no. 13, 142-150.

McIntyre, A., and W. F. Ruddiman, 1972: Northeast Atlantic post-Eemian paleoceanography. A predictive analog of the the future, *Quaternary Res.* 2:350-354.

Matthews, R. K., 1972: Dynamics of the ocean-cryosphere system: Barbados data, *Quaternary Res.* 2(3):368-373.

Matthews, R. K., 1973: Relative elevation of Late Pleistocene high sea level stands: Barbados uplift rates and their implications, *Quaternary Res.* 3(1):147-153.

Moore, T. C., Jr. 1973: Late Pleistocene-Holocene Oceanographic changes in the northeastern Pacific, *Quaternary Res.* 3(1):99-109.

Moore, Ted C., Jr. 1973: Method of randomly distributing grains for microscopic examination, *J. Sediment. Petrol.* 43(3):904-906.

Pisias, N., J. P. Dauphin, and C. Sancetta, 1973: Spectral analysis of Late Pleistocene-Holocene sediments, *Quarternary Res.* 3(1):3-9.

Ruddiman, W. F. and A. McIntyre, 1973: Time-transgressive deglacial retreat of polar waters from the North Atlantic, *Quarternary Res.* 3:117-130.

Sachs, H. M., 1973: Late Pleistocene history of the North Pacific: Evidence from a quantitative study of Radiolaria in core V21-173, *Quaternary Res.* 3:89-98.

Sachs, H. M., 1973: North Pacific radiolarian assemblages and their relationship to oceanographic parameters, *Quaternary Res.* 3:73-88.

Sachs, H. M., 1975: Radiolarian-based estimate of north Pacific summer sea-surface temperature regime during the latest glacial maximum, in *Climate of the Arctic, AAAS-AMS Symp., Fairbanks, Alaska 1973*, G. Weller (ed.).

Sancetta, C., J. Imbrie, N. G. Kipp, A. McIntyre, and Ruddiman, W. F. 1972: Climatic record in north Atlantic deep-sea core V23-82: Comparison of the last and present interglacials based on quantitative time series, *Quaternary Res.* 2:363-367.

Sancetta, C., J. Imbrie, and N. G. Kipp, 1973: Climatic record of the past 130,000 years in north Atlantic deep-sea core V23-82: Correlation with the terrestrial record, *Quaternary Res.* 3(1):110-116.

Shackleton, N. J. and N. D. Opdyke, 1973: Oxygen isotope and paleomagnetic stratigraphy of Equatorial Pacific core V28-238: Oxygen isotope temperatures and ice volumes on a 10^5 year and 10^6 year scale, *Quaternary Res.* 3(1):39-55.

Steinen, R. P., R. S. Harrison, and R. K. Matthews, 1973: Eustatic low stand of sea level between 125,000 and 105,000 B.P.: Evidence from the sub-surface of Barbados, West Indies, *Geol. Soc. Amer. Bull.* 84(1):63-70.

Steinen, Randolph P. and R. K. Matthews, 1973: Phreatic vs. vadose diagenesis: Stratigraphy and mineralogy of a cored borehole on Barbados, W.I., *J. Sediment. Petrol.* 43(4): 1012-1020.

Streeter, S. S., 1973: Bottom water and benthonic foraminifera in the North Atlantic—glacia-interglacial contrasts, *Quaternary Res.* 3:131-141.

Thompson, Peter R., 1974: Pacific Pleistocene sediments: Planktonic Foraminifera dissolution cycles and geochronology, *Geology* 2(7): 333-335.

Vankatarathnam, K. and P. Biscaye, 1973: Clay mineralogy and sedimentation in the Eastern Indian Ocean, *Deep-Sea Res.* 20:727-738.

In Press

Bé, A. W. H., J. Damuth, L. Lott, and R. Free, 1975: Late Quaternary climatic record in western Equatorial Atlantic sediments, in *Geol. Soc. Amer. Mem.* 145, Cline and Hays (eds.), 79 pp.

Birks, H. J. B., T. Webb, III, and A. A. Berti, 1975: Numerical analysis of surface pollen samples from Central Canada: A comparison of methods, in *Review of Paleobotany and Palynology*.

Biscaye, P., R. Chesselet, and J. M. Prospero, 1975: Rb-Sr, 87Sr/86Sr isotope system as an index of provenance of continental dusts in the open Atlantic Ocean, *Journal de la Recherche Atmospherique*.

Davis, R. B., and T. Webb, III, 1975: The contemporary distribution of pollen in eastern North America: A comparison with the vegetation, *Quaternary Res.*

Denton, G. H., and W. Karlen, 1975: Holocene climatic variations: Glacier and tree-line variations in the White River Valley and Skolai Pass, Alaska, and their implications, in *Geol. Soc. Amer. Bull.*, 81 pp.

Gardner, J. V., and L. H. Burckle, 1975: Upper Pleistocene *Ethmodiscus Rex* oozes from the eastern equatorial Atlantic, *Micropaleontology*.

Gardner, J. V., and J. D. Hays, 1975: The eastern equatorial Atlantic: Sea-surface and temperature and circulation responses to global climatic change during the past 200,000 years, in *Geol. Soc. Amer. Mem.* 145, Cline and Hays (eds.), 52 pp.

Geitzenauer, K., M. Roche, and A. McIntyre, 1975: Modern Pacific coccolith assemblages: Derivation and application to Late Pleistocene paleotemperature analysis: in *Geol. Soc. Amer. Mem.* 145, Cline and Hays (eds.), 52 pp.

Hays, J. D., J. Lozano, N. J. Shackleton, and G. Irving, 1975: An 18,000 year B.P. reconstruction of the Atlantic and western Indian sectors of the Antarctic Ocean, in *Geol. Soc. Amer. Mem.* 145, Cline and Hays (eds.), 79 pp.

Heath, G. R. 1975: Processes controlling siliceous biogenous deposits, in *Marine plankton and sediments*, W. R. Riedel and T. Saito (eds.), Micropaleontology Press, 85 pp.

Heath, G. R., T. C. Moore, and P. Dauphin, 1975: Late Pleistocene-Holocene variations in the accumulation rates of opal, quartz, organic carbon, and calcium carbonate in the Cascadia Basin area, northeast Pacific, in *Geol. Soc. Amer. Mem.* 145, Cline nd Hays (eds.), 42 pp.

Kellogg, T. B., 1975: Late Quaternary climatic changes: Evidencefrom Norwegian and Greenland Sea Deep-sea cores, in *Geol. Soc. Amer. Mem.* 145, Cline and Hays (eds.), 73 pp.

Kellogg, T. B., 1975: Late Quaternary climatic changes in the Norwegian and Greenland Seas, in *Proceedings of the 24th Alaskan Scientific Conference, 1973, Fairbanks, Alaska*.

Kipp, N. G., 1975: New Transfer function for estimating past sea-surface conditions from the sea-bed distribution of Planktonic Foraminiferal assemblages in the North Atlantic, in *Geol. Soc. Amer. Mem.* 145, Cline and Hays (eds.), 117 pp.

Kukla, G. J., 1975: Milankovitch and climate: The missing link? in *Nature*, 26 pp.

Lozano, J. and J. D. Hays, 1975: The relationship of radiolarian assemblages to sediment types and physical oceanography in the Atlantic and western Indian sectors of the Antarctic Ocean, in *Geol. Soc. Amer. Mem.* 145, Cline and Hays (eds.), 91 pp.

McIntyre, A., N. G. Kipp, A. W. H. Bé, T. J. Crowley, T. Kellogg, J. V. Gardner, W. Prell, and W. F. Ruddiman, 1975: The glacial North Atlantic 18,000 years ago: A CLIMAP reconstruction, in *Geol. Soc. Amer. Mem.* 145, Cline and Hays (eds.), 67 pp.

Ninkovich, D. and J. H. Robertson, 1975: Volcanogenic effects on the rates of deposition of sediments in the northwest Pacific Ocean, *Geology*, 27 pp.

Ninkovich, D. and N. J. Shackleton, 1975: Distribution, stratigraphic position and age of ash layer "L" in the Panama Basin region, Earth *Planet. Sci. Lett.* 37 pp.

Pisias, N., G. R. Heath, and T. C. Moore, Jr., 1975: Lag times for oceanic responses to climatic change, *Nature,* 10 pp.

Pisias, N., 1975: Late Quaternary variations in sedimentation rate in the Panama Basin and the identification of orbital frequencies in carbonate and opal deposition rates, in *Geol. Soc. Amer. Mem.* 145, Cline and Hays (eds), 43 pp.

Prell, W. and J. D. Hays, 1975: Late Pleistocene faunal and temperature patterns of the Colombia Basin, Caribbean Sea, in *Geol. Soc. Amer. Mem.* 145, Cline and Hays (eds.), 58 pp.

Prell, W., J. V. Gardner, A. W. H. Bé, and J. D. Hays, 1975: Equatorial Atlantic and Caribbean faunas, temperatures, and circulation: interglacial versus glacial, in *Geol. Soc. Amer. Mem.* 145, Cline and Hays, (eds.), 49 pp.

Ruddiman, W. F. and A. McIntyre, 1975: Northeast Atlantic Paleoclimatic changes over the last 600,000 years, in *Geol. Soc. Amer. Mem.* 145, Cline and Hays (eds.), 103 pp.

Sachs, H. M., 1975: Evidence for the role of the oceans in climatic change: Tests of Weyl's theory of ice ages, in *J. Geophys. Res.*

Saito, T., P. R. Thompson, and D. Breger, 1975: Skeletal ultramicrostructure of some elongate-chambered planktonic Foraminifera and related species, in *Progress in Micropaleontology,* selected papers in honor of Kiyoshi Asano.

Shackleton, N. J. and N. D. Opdyke, 1975: Oxygen isotope and paleomagnetic stratigraphy of Pacific core V28-239: Late Pliocene to Latest Pleistocene, in *Geol. Soc. Amer. Mem.* 145, Cline and Hays (eds.), 46 pp.

Thiede, J., 1974: Shell- and skeleton-producing plankton and nekton in the eastern North Atlantic Ocean, in *"Meteor" Forsch. Ergebn.,* C, 50 pp.

Thiede, J., Living planktonic foraminifera in a coastal upwelling area, *Nature,* 7 pp.

van Donk, Jr., 1975: An O^{18} record of the Atlantic Ocean for the entire Pleistocene, in *Geol. Soc. Amer. Mem.* 145, Cline and Hays (eds.), 39 pp.

Venkatarathnam, K., A. W. H. Bé, and P. E. Biscaye, 1975: Calcium carbonate distribution in the surface sediments of the Indian Ocean, in *J. Geophys. Res.*

Webb, T., III, and J. H. McAndrews, 1975: Corresponding patterns of contemporary pollen and vegetation in central North America, in *Geol. Soc. Amer. Mem.* 145, Cline and Hays (eds.).

Seabed Assessment Program

This program has as its objective the resolution of questions concerning geologic processes along continental margins, mid-ocean ridges, and deep-ocean basins. A better understanding of sea-floor processes will help in locating hydrocarbon and metallic accumulations and other products of economic significance. These studies, which do not duplicate the efforts of oil and mining companies, are broadly grouped as Continental Margin Studies, Plate Tectonics and Metallogenesis Studies, and Manganese Nodule Study.

Projects supported by IDOE are, whenever possible, based on recommendations prepared by participants in scientific workshops sponsored by the Intergovernmental Oceanographic Commission (IOC). Scientists from universities, government, and industry, who are investigating the phenomena of interest, are invited to participate in the workshops. Objectives are to determine the present status of knowledge within the related scientific discipline, to identify major gaps in that knowledge, to recommend the needed research, and develop a strategy for conducting the studies. International cooperation and participation is emphasized. Exchange of personnel among countries is encouraged, but each country is expected to bear its own share of the cost.

Continental Margin Studies

The continental margin is being studied to better understand the rifting of continental land masses and the effects of the rifting on the margins. Of special concern are aspects of rifting process that relate to formation of hydrocarbon and mineral deposits. Studies include the African Atlantic Margin, the Southwest Atlantic Margin, and the Caribbean Margin.

Up comes a seismic energy source gun, operated by compressed air.

African Atlantic Margin

The east atlantic continental margin work of the African coast was designed by K. O. Emery of the Woods Hole Oceanographic Institution in 1971 to learn more about the separation of Africa and South America and the subsequent history and development of the African continental margin and deep-ocean floor. The first major shipboard investigation to be completed was the continental margin off southwestern Africa. This area lies southeast of the Walvis Ridge and includes the western part of Agulhas Plateau, Agulhas Basin, Cape Rise, and Cape Basin. Traverses approximating 17,000 km of continuous gravity, magnetic, and seismic-reflection profiles were recorded to determine the structure of the continental margin from Cape St. Francis to Walvis Ridge, and of the adjacent Agulhas and Cape deep-ocean basins (figs. 10 and 11).

These and previous sea-floor and land data suggest that basement structures are the result of the breakup of Gondwanaland and the dispersion of the fragments to their present positions. This breakup may have been initiated as early as the Carboniferous Period, but most of the dispersion has taken place since Middle Jurassic. Igneous activity during the early phase may have led to the emplacement of ridges along the continental margin. Later, block faulting and volcanism along the fracture zones that delineate the flow lines of the drifting continents produced Walvis Ridge, Cape Rise, and the Agulhas Plateau. One of these fracture zones, the Agulhas fracture zone, dominates the structural grain of the continental margin and deep-ocean floor off the African southern coast.

Sediments as thick at 7 km buried the fragmented continental basement and adjacent oceanic basement off the west coast and formed a broad continental rise and abyssal plain within Cape basin. This work is described by Emery and others (1975).

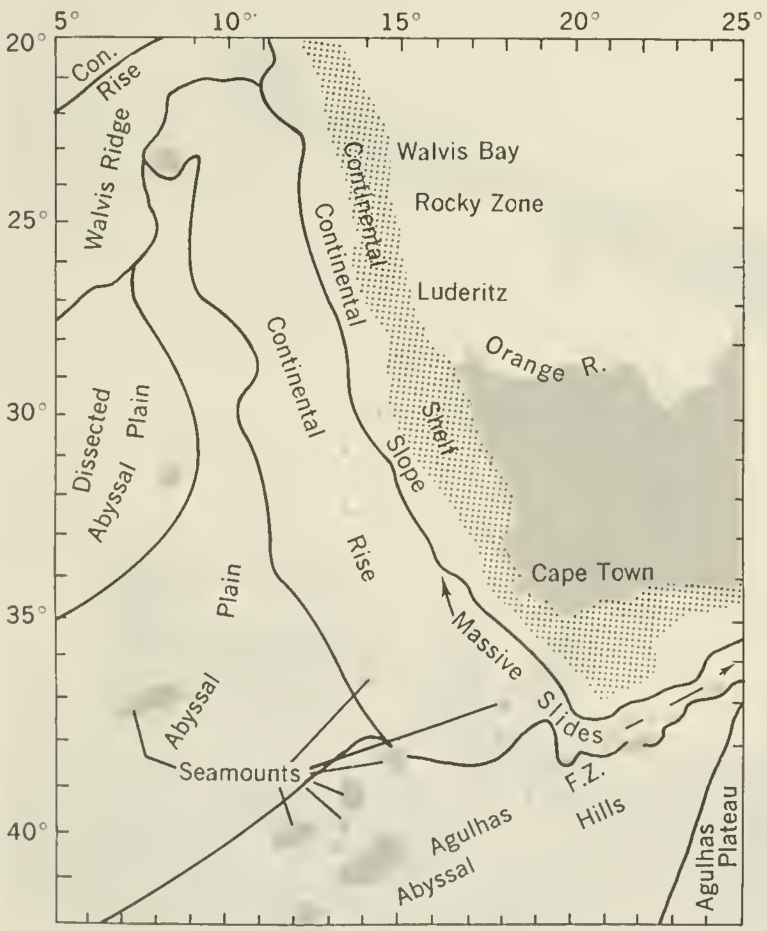


Figure 10.—Major physiographic units of southwest Africa continental margin.

Work completed on the west African continental margin between Angola and Sierra Leone includes about 30,750 km of geophysical traverses (seismic reflection and refraction, magnetics, and gravity) by the RV ATLANTIS II. These traverses, supplemented by about 50,000 km of traverses by other ships, provide a basis for mapping and understanding the geological structure, history, and origin of the region.

The deep indentation in the coastal configuration of western Africa is paralleled by a similar bend of the Mid-Atlantic Ridge, and by the prominent bulge of northeastern Brazil. These sharp bends are due to left-lateral offsets by numerous transform faults in a belt of equatorial fracture zones. Some of the fracture zones continue eastward to intersect the entire length of the east-west coast of the Gulf of Guinea and to penetrate the continent at the Benue Trough or graben. Valleys of the fracture zones have been sites of sediment deposition, whereas the ridges have served as dams that force the sediment to move westward. This work is described by Emery and others (1975).

Where enormous quantities of sediment have been delivered to the ocean by the Niger-Benue rivers, a large delta has deeply buried the irregular topography of the fracture zones. The entire belt of fractured ocean floor, continental margin, and continent derives its structural, physiographic, and stratigraphic characteristics from lateral movement, or translation, of the ocean floor with respect to the continent. Petroleum prospects appear to be far greater in the Niger Delta and the region of divergence south of it than in the entire region west of the delta. The favorable continental margin contains thicker sediments, large ancient and modern deltas, and salt and mud diapirs produced by the weight of overlying sediments (Emery, 1974).

Marine geophysical data received last year by NOAA Environmental Data Service's National Geophysical and Solar-Terrestrial Data Center include 24,000 nautical miles of bathymetric, magnetic, gravity, seismic-reflection profile, and 3.5-kHz echo sounder data.

Southwest Atlantic Margin

Since early 1972 the National Science Foundation has provided support for a geophysical study of the continental margin of Argentina and Brazil. This study is being conducted by the Lamont-Doherty Geological Observatory in cooperation with scientific and governmental agencies of Argentina, Brazil, Chile, and the United Kingdom. The overall objective is to determine the present structure of a rifted margin, and to infer from this structure the early history of continental rifting.

Research and study of the Brazilian Margin during the year has made it possible to: determine the age and evolution of the Amazon Cone; determine the origin and age of compressional structures on the shelf off Brazil; acquire a better understanding of the westward extensions of the equatorial fracture zones, and of the consequent suggestion that the North Brazilian Ridge consists only of marginal fracture ridges (a hypothesis substantiated by two-ship refraction profiles); outline the sedimentary history of the Fernando de Noronha ridge, basin, and Equatorial Mid-Ocean canyon; better understand the sedimentation processes on the Brazilian continental mar-

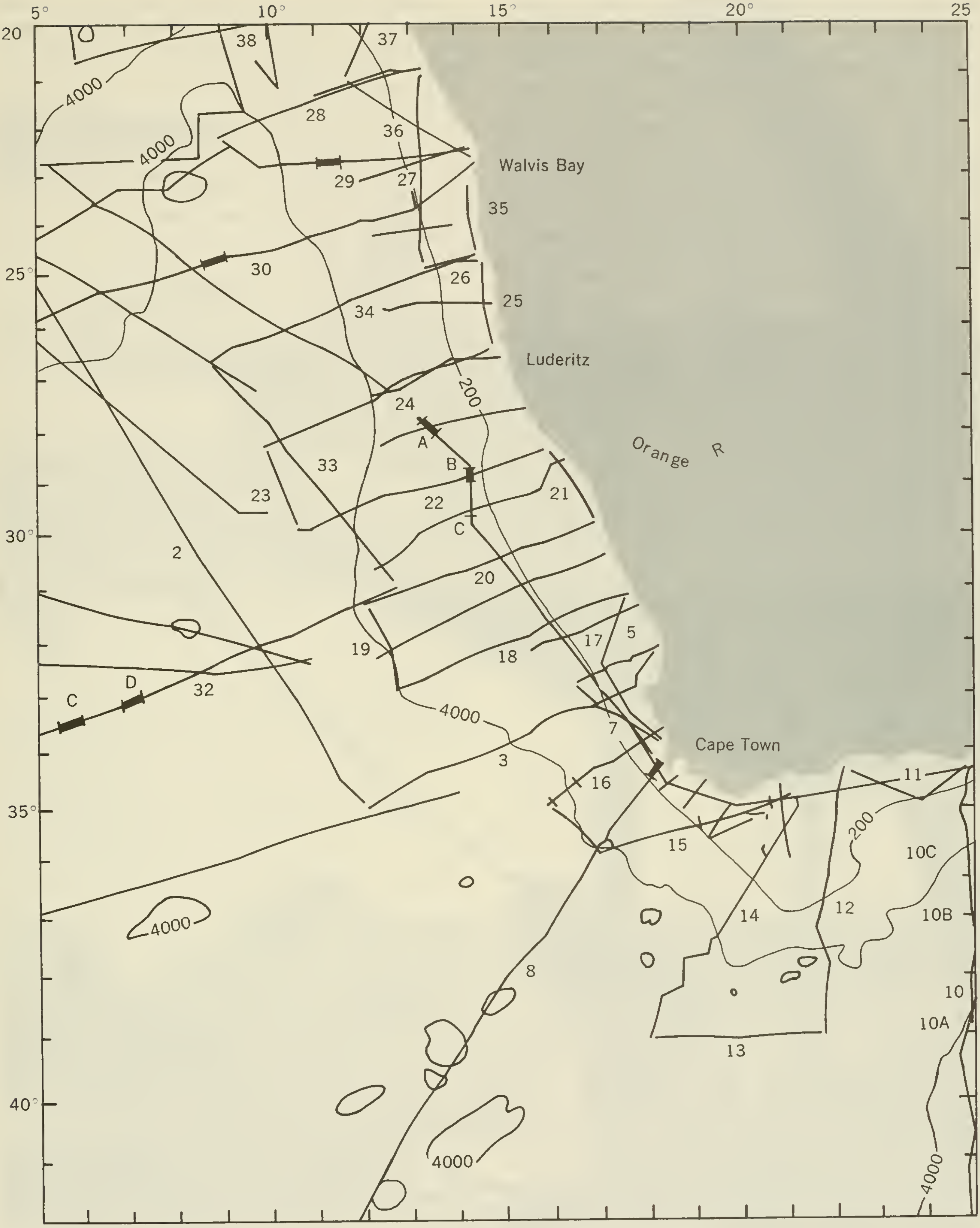


Figure 11.—Geophysical traverses across southwest African continental margin.

gin; continue study of the crustal structure, sediments, bathymetry, and origin of the Ceara rise; delineate the diapir zone on the eastern margins of Brazil; map basement structure and sediment thickness in the Pelotas and Santos basins and inter-basin area; and complete petrologic studies of rocks dredged from the Sao Paulo Plateau and Rio Grande Rise.

Marine geological work in the Argentine Basin has followed two lines of micropaleontologic study: 1) analyses of pre-Pleistocene cores from the Falkland Plateau, the continental rise, and the continental slope to determine the evolution of the Argentine Continental Margin; and 2) use of Antarctic-source diatoms as tracers to the flow of Antarctic Bottom Water and as indicators of source of sediments.

Terrestrial geology studies include detailed work on the Lower Cretaceous ophiolite complex in the southern Andes and its relation to and significance for the southern Andean Cordillera. Collections were made for paleomagnetic work and for geochemical studies to determine the tectonic significance of igneous rocks from the Andean Cordillera and from the Quaternary mafic vents, flows, and intrusions east of the Andes.

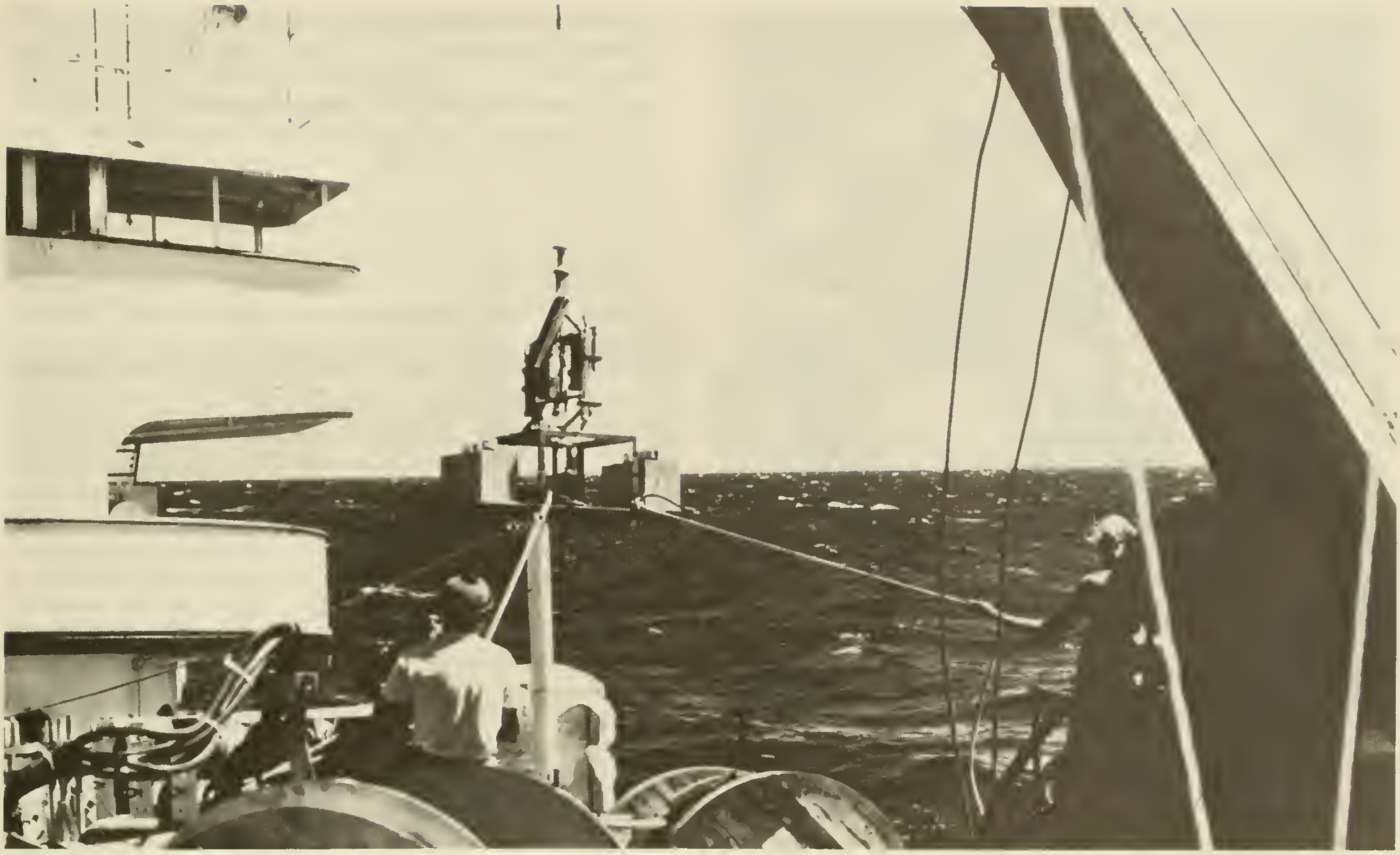
Marine geological and geophysical field work for the study of the Argentine Margin was completed with a coring and dredging program in the submarine canyons along the Argentine continental rise and slope. The sediment cores, taken in a number of outcrop areas, are being studied to identify the ages and lithologies of major stratigraphic units observed in the seismic data collected during earlier phases of the study.

Recent seismic work included: surveys between coring sites to aid geologic correlation of samples; a refraction study of the continental rise using sonobuoys, an ocean-bottom seismograph, and two ships for recording; and a retraverse of canyon areas sampled on the previous leg. Continuing research includes studies of the basins and shelf, the ocean-continent transition, and the Falkland Plateau and North Scotia Ridge.

Gravity and magnetic anomalies in the Argentine Basin have been compared with similar features off southern Africa. These results are very promising for further study and interpretation of: the direction and relative motion between Africa and South America when rifting was initiated, the precise time of the early opening, and the relationship between the structures on the continental margin and its history of early opening.

Southwest Atlantic continental margin work accomplished includes three periods of marine field work of about 6 months each (early 1972, 1973, and 1974) and field work in the southern end of the Andean Cordillera and on the island of South Georgia (early 1973 and 1974). This work is reported in: Progress Report: A Geophysical Study of the Continental Margin of Argentina and Brazil, Lamont-Doherty Geological Observatory of Columbia University, undated, Reference Grant GX 34410. Marine geophysical data received in 1973 by NOAA Environmental Data Service's National Geophysical And Solar-Terrestrial Data Center include 30,000 nautical miles of bathymetric, magnetic, seismic-reflection profile, 3.5-kHz echo sounder, and sonobuoy data.

Tossing overboard a sonobuoy.



Down goes an Ocean-bottom seismometer (OBS) with self-contained power.

The Brazilian margin study was undertaken in cooperation with Reconhecimento da Margem Continental Brazileira (REMAC), which represents the following organizations:

Petroleo Brasileiro SA (Petrobrás)
Departamento Nacional da Produção Mineral (DNPM)
Companhia de Pesquisa de Recursos Minerais (CPRM)
Conselho Nacional de Pesquisa (CNPq)
Diretoria de Hidrografia e Navegação (DHN)

Personnel from these organizations participated in the scientific work at sea and in the subsequent data analysis.

The Argentine margin study was undertaken with the cooperation of the Consejo Nacional de Investigaciones Cientificas y Tecnicas and the Argentine Navy. The Instituto Argentino de Oceanografia participated in the scientific work at sea and in the subsequent analysis of the data. Associated geologic studies on land involved cooperative projects with the Dirección Nacional de Geologia y Mineria in Buenos Aires, the Empresa Nacional del Petroleo in Punta Arenas, Chile, and the British Antarctic Survey which administers the island of South Georgia.

Continental Margin Research Papers

Papers resulting from research under grant GX-34410 follow:

Barker, P. F., and Ian W. D. Dalziel, 1974: Preliminary results of Deep Sea Drilling Project Leg 36: The southernmost Atlantic Ocean Basin, *Geol. Soc. Amer. Abstr. with Programs* 6(7):644-645.

Bryan, G. M., N. Kumar, and P. M. de Castro, 1973: The North Brazilian Ridge and the extension of equatorial fracture zones into the continent, in *Trans. 26th Brazilian Geol. Cong.* pp. 133-144.

Dalziel, Ian W. D., and D. H. Elliot, 1973: The Scotia Arc and Antarctic Margin, in A. E. M. Nairn and F. G. Stehli (eds.), *The Ocean Basins and Margins*, 1. The South Atlantic, Plenum Press, New York, pp. 171-245.

Dalziel, I. W. D., R. Kligfield, W. Lowrie, and N. D. Opdyke, 1973: Paleomagnetic data from the southernmost Andes and the Antarctandes, in D. H. Tarling and S. K. Runcorn (eds.), *Implications of Continental Drift to the Earth Sciences*, Vol. 1, Academic Press, London, pp. 87-101.

Dalziel, I. W. D., 1974: Margins of the Scotia Sea, in *The Geology of Continental Margins*, C. A. Burk and C. L. Drake (eds.), Springer-Verlag, New York, pp. 567-579.

Dalziel, Ian W. D., Martin J. de Wit, and Keith F. Palmer, 1974: A fossil marginal basin in the Southern Andes, *Nature* 250(10):291-294.

Dalziel, Ian W. D., and Keith F. Palmer, 1974: Progressive deformation and orogenic uplift at the southern extremity of the Andes, *Geol. Soc. Amer. Abstr. with Programs* 6(7):705.

Dalziel, I. W. D., 1973. Evolution of the southern Andes, Tectonic studies Group of London Geological Society, presented at Newcastle, England.

Dalziel, I. W. D., R. H. Dott, Jr., R. D. Winn, Jr., and R. L. Bruhn, 1975: Tectonic relations of South Georgia Island to the southernmost Andes, *Geol. Soc. Amer. Bull.* 86(7):1034-1040.

Damuth, J. E., and Kumar, N., 1974: Distribution of coarse terrigenous sediments on the outer continental margin: Western Equatorial Atlantic (Abstract), *Amer. Assoc. Pet. SEPM Annual Convention in San Antonio.*

Damuth, John E., and Marcus A. Gorin, 1974. The equatorial Mid-Ocean Canyon, *Geol. Soc. Amer. Abstr. with Programs* 6(7):705.

Damuth, John E., and Naresh Kumar, 1975: Amazon Cone: Morphology, sediments, age, and growth pattern, *Geol. Soc. Amer. Bull.* 86(6):863-878.

Emery, K. O., 1974: Pagoda structures in marine sediments, in *Natural Gases in Marine Sediments*, I. R. Kaplan (ed.), Plenum Publishing Corp., New York, Vol. 3, Marine Science Series 309-317.

Emery, K. O., E. Uchupi, J. Phillips, C. Bowin, and J. Mascle, 1974: The continental margin off Western Africa: Angola to Sierra Leona, National Science Foundation, *Woods Hole Oceanogr. Insti. Tech.* Rep. Ref. No., WHOI-74-99.

Emery, K. O., Elazar Uchupi, C. O. Bowin, Joseph Phillips, and Simpson, E. S. W., 1975: Continental margin off Western Africa: Cape St. Francis (South Africa) to Walvis Ridge (South-West Africa), *Amer. Assoc. Pet. Geol. Bull.* 56(1):3-59.

Gorini Marcus A., John E. Damuth, and George M. Bryan, 1974: The Fernando de Noronha Ridge and its relationship to equatorial Atlantic fracture zones, *Geol. Soc. Amer. Abstr. with Programs*, 6(7):762.

Gorini, M., and G. M. Bryan, 1974: A semi-isolated basin off the northwestern Brazilian margin, *55th Amer. Geophys. Unio Meetings*, Washintong, D. C.

Hays, James D., and W. C. Pitman, III,1973: Lithospheric plate motion, Sea level changes and climatic and ecological consequences, *Nature* 245(5427):18-22.

Leyden, R., and J. P. Nunes, 1973: Diapiric structures offshore southern Brazil, in *Trans. 26th Brazilian Geol. Congr.*, 45-50.

Leyden, Robert, and George Bryan, 1973: The eastern Brazilian margin in relation to the early South Atlantic, (Abstract), *EOS, Trans. Amer. Geophys. Union* 54(4):333.

Rabinowitz, Philip D., 1974: Gravity anomalies in the continental margin of Angola Africa: Aeply, *J. Geophys. Res.* 79(11):1727-1728.

Rabinowitz, P., 1974: The boundary between oceanic and continental basement in the western North Atlantic Ocean, in *Geology of Continental Margins*, C. Burk and C. Drake (eds.), Springer-Verlag, New York, 67-84.

Stoffa, Paul, Peter Buhl, and George M. Bryan, 1974: Cepstrum aliasing and the calculation of the Hilbert transform, *Geophys.* 39(4):543-544.

In Press

Burckle, L. H., and D. Stanton, In press. Distribution of displaced Antarctic diatoms in the Argentine Basin, *Nova Hedwegia.*

Dalziel, I. W. D., In press. The sub-Antarctic Islands, in *Encyclopedia of Earth Sciences:* VIII. World Regional Geology, R. W. Fairbridge (ed.), Van Nostrant Reinhold Co., New York.

Dalziel, I. W. D., R. Caminos, K. F. Palmer, F. Nullo, and R. Casanova, In press. The southern extremity of the Andes: The geology of Isla de Los Estos, Argentina Tierra del Fuego, *Amer. Assoc. Pet. Geol. Bull.*

Dalziel, I. W. D., and K. F. Palmer, In press. Progressive deformation and orogenic uplift at the southernmost extremity of the Andes, *Geol. Soc. Amer. Bull.*

Leyden, R., H. Asmus, S. Zembruski, and G. Bryan. In press. South Atlantic diapiric structures, *Amer. Assoc. Pet. Geol.*

Plate Tectonics and Metallogenesis Studies

Field activities and continuing study of the Nazca Plate, Mid-Atlantic Ridge, and East and Southeast Asia are described. Project descriptions, objectives, and accomplishments through April 1974 appear in *International Decade of Ocean Exploration Progress Report Volume 3*, April 1973 to April 1974, December 1974.

Nazca Plate

Recent seismic refraction and seismic reflection investigations by the Hawaii Institute of Geophysics (HIG), University of Hawaii, in the Peru-Chile Trench area (fig. 12), together with analyses of bathymetry, geomorphology, volcanism, and seismicity, indicate significant north-south crustal change along the trench. Other HIG studies have provided a detailed chronological orientation for sea-floor spreading patterns. These show changes in dynamic spreading patterns in the eastern Pacific during the Miocene (about 25 million years before

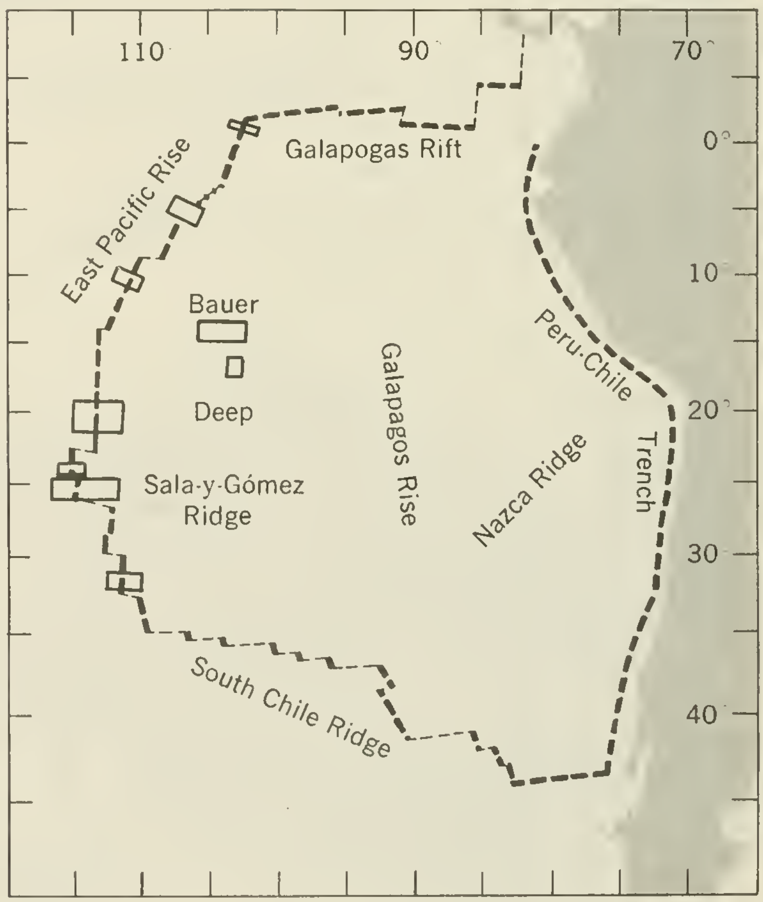


Figure 12.—Nazca Plate.

the present) would have necessitated corresponding changes along all plate boundaries in the Pacific, perhaps even worldwide.

Geochemical studies of Nazca Plate sediments by Oregon State University (OSU) provide increasing evidence that seawater hydrothermal systems extract and transport metals initially disseminated in newly crupted submarine volcanic rocks, that this fundamental geochemical process influences the composition of seawater, and that this process has led to formation of a variety of economically important ore bodies now preserved on the continents. Examples are: massive sulfides in Precambrian greenschist belts, such as the Noranda deposits of the Abitibi belt in Canada; gold ores in possible Precambrian "metalliferous sediment" of the Homestake mine of South Dakota; the Precambrian Jerome Arizona copper ores; the massive sulfides of the Troodos ophiolite complex on Cyprus, deposited in Cretaceous seas; and the Miocene Kuroko ore bodies in Japan.

Scientists of Stanford University and the U.S. Geological Survey are investigating the origin of heavy metals and deposits at divergent plate boundaries. Preliminary laboratory experiments indicate that within 1,500 hours adequate amounts of iron, manganese, copper, lead, and silver are transferred from basalt into seawater in concentrations adequate for generation of heavy metal deposits.

Work at the University of Texas at Dallas is directed to determining the age and genesis of rocks from northern Chile, particularly the paleogeography of the area as it relates to the geologic evolution and interaction of continental South America and the Nazca Plate. Samples of igneous rocks crop out with copper quartz porphyries in northern Chile are being compared with oceanic crust and sediments from the Nazca Plate for Sr^{87}/Sr^{86} ratios. This research attempts to use Sr isotopes to explain the origin of copper-rich quartz porphyries and the age of associated hydrothermal alterations.

Approximately 22,000 nautical miles of trackline data from the RV Kana Keoki (HIG), 12,000 from the RV Yaquina (OSU), and 32,000 from the OSS Oceanographer (NOAA Pacific Marine Environmental Laboratory) were received last year by NOAA Environmental Data Service's National Geophysical and Solar-Terrestrial Data Center, including bathymetric, magnetic, seismic-reflection profile, 3.5-kHz echo sounder, and sonobuoy data.

Mid-Atlantic Ridge

During Project FAMOUS (French American Mid-Ocean Undersea Study) dives scientists in submersibles followed a detailed mission plan, recording observations and collecting samples, while other members of the team at the surface monitored progress and the minute-to-minute location of the submersible. The resulting information includes: more than 100,000 photographs of the seabed; a set of rock, sediment, and water samples from precisely known locations; and the first direct observations of faults and lava flows of newly formed sea floor.

Until Project FAMOUS, there had been little success in bridging the gap between small-scale features of the ocean floor and larger geologic features, because single dredge samples and bottom photographs could not be located more accurately than about 100 meters. By using submersibles to explore the rift valley, locations of samples were determined to within 10 meters or less, making it possible to construct traditional geologic maps. Studies of the photographs and samples are providing new information on sea-floor spreading, formation of new crust, and hydrothermal emplacement of minerals.

The FAMOUS (French-American Mid-Ocean Undersea Study) shoulder patch.

Results of Glomar Challenger drilling, 20 miles from the FAMOUS dive sites, have been summarized in Deep Sea Drilling Project, Leg 37, 11 September 1974. Hole 332A, where water depth was 1,841 meters, was drilled to 1,858 meters beneath the sea floor and then continuously cored to a total depth 2,228 meters. Examination of the cores shows the following: The upper part of the volcanic oceanic layer is made up of submarine basalt flows interlayered with deep sea sediments. The relative abundance of sediment decreases with depth until only volcanic rocks are encountered. The accumulation of this volcanic-sedimentary sequence occurred over a period of 100,000 to 200,000 years on the floor of the median valley (in the Mid-Atlantic Ridge). New crust formed during cycles of massive eruptions, which periodically decreased in their activity and permitted deep sea sediments to collect on top of the lava flows between eruptions. A number of repetitive volcanic cycles have been identified in this sequence. A few unique types of lava interrupt the cycles at odd intervals.

Deep drilling also has been completed in an active geothermal area in the Azores. In 1972, scientists from Dalhousie University and Lamont-Doherty Geological Observatory began deep drilling on the island of Bermuda in the western Atlantic. This 800-meter hole into the oceanic crust showed some 100 separate volcanic units. In 1973, a second hole was drilled on the island of São Miguel in the Azores (Muecke, M. J. and others. Deep drilling in an active geothermal area in the Azores, *Nature* 252(5841):281-285, November 22, 1974). Tempera-

tures greater than 200°C were encountered at a depth of 800 meters. The presence of subaerial volcanics at 786 meters below sea level indicates subsidence of the island at a rate of 0.1 centimeter per year during the past 69 million years.

East and Southeast Asia

This program of research within the International Decade of Ocean Exploration is under the sponsorship of the Committee for Coordinaion of Joint Processing for Mineral Resources in Asia Offshore Areas and the Intergovernmental Oceanographic Commission (IOC). Proposals for continued studies include production of a geological and geophysical atlas of water-covered portions of east and southeast Asia and a synthesis of existing data. All available data will be brought together to analyze the plate kinematics and related processes. Compilation and publication of an atlas will be by the Lamont-Doherty Geological Observatory in cooperation with investigators from Cornell University, Scripps Institution of Oceanography (SIO), and Woods Hole Oceanographic Institution. SIO will compile and contour bathymetric data and provide geochemical and petrographic data by augmenting its data collection and preparing maps of sediment properties. Other scientists will cooperate in studies of seismic reflection profiles, magnetism, gravity (free-air and Bouguer anomalies), heat flow data, and deep crustal structure. Field work will be carried out in areas like the Banda Sea, Java Trench, and Phillipine Islands, where the synthesis program indicates additional data are necessary.

Project FAMOUS Research Papers

Anonymous, 1974: Rapport de Mission FAMOUS 1974, *CNEXO Section des Engins*, September 23.

Bellaiche, G., J. L. Cheminee, J. Francheteau, R. Hekinian, X. Le Pinchon, H. D. Needham, and R. D. Ballard, 1974: Inner floor of the Rift Valley: First submersible study, *Nature* 250( ):558-560.

Bougault, H., and R. Hekinian, 1974: Rift valley in the Atlantic Ocean near 36°50′N; petrology and geochemistry of basaltic rocks, *Earth Planet. Sci. Lett.* 24(2):249-261.

Brundage, W. L., H. S. Fleming, and N. Cherkis, 1974: *Preliminary NRL LIBEC/FAMOUS Lineations Report.*

Detrick, R., J. D. Mudie, B. P. Luyendyk, and K. C. Macdonald, 1973: Near-bottom observations of an active transform fault: Mid-Atlantic Ridge at 37°N, *Nature* 246( ):59.

Fowler, C. M. R., and D. H. Mathews, 1974: Seismic refraction experiment on the Mid-Atlantic Ridge in the FAMOUS area, *Nature* 249(5459):752-754.

Greenewalt, David, and P. T. Taylor, 1974: Deep-tow magnetic measurement across the axial valley of the Mid-Atlantic Ridge, *J. Geophys. Res.* 79( ):4401-4405.

Heirtzler, J. R., 1973: Project FAMOUS planning Mid-Atlantic Ridge investigation, *Mar. Tech. Soc. J.* 7(1):14-15.

Heirtzler, J. R., 1974: FAMOUS: A plate tectonics study of the genesis of the Lithosphere, *Geology* 2(6):273-378.

Scientist-diver reviews data prior to ALVIN dive during Project FAMOUS.

Hekinian, R., M. Chaigneau, and J. L. Cheminee, 1974: Popping rocks and lava tubes from the Mid-Atlantic rift valley at 36°N, *Nature* 245 (5425):371-373.

Le Pichon, X., 1974: Le Projet FAMOUS: Pour Quoi Faire? *La Recherche,* 5:674.

Moore, James G., Henry S. Fleming, and Joseph D. Phillips, 1974: Preliminary model for extrusion and rifting at the axis of the Mid-Atlantic Ridge, 36°48′ north, *Geology* 2(9):437-440.

Needham, H. D., and J. Francheteau, 1974: Some characteristics of the rift valley in the Atlantic Ocean near 36°48′ north, *Earth Planet. Sci. Lett.* 22(2):29-43.

Poehls, K., 1974: Seismic refraction on the Mid-Atlantic Ridge at 37°N, *J. Geophys. Res.* 79(23):3370-3373.

Reid, Ian, and Ken C. Macdonald, 1973: Microearthquake study of the Mid-Atlantic Ridge near 37°N using sonobuoys, *Nature* 246(5428):88-90. Nov. 9.

Spindel, R. C., S. B. Davis, K. C. Macdonald, R. P. Porter and J. D. Phillips, 1974: Microearthquake survey of median valley of the Mid-Atlantic Ridge at 36°30′N, *Nature* 248 (5499):577-579 Nov. 30.

Whitmarsh, R. B., 1973: Median valley refraction line, Mid-Atlantic Ridge at 37°N, *Nature* 246(5430):297-299.

In Press

Anderson, Susan H. A close look at the lithosphere plate boundary between the North Atlantic and African plates, *NOAA Journal.*

Arcyora, X. Y. Transform fault and rift valley geology by bathyscaphe and diving saucer, *Science.*

Arcyora, X. Y. Le Projet FAMOUS: Premier Bilan, *La Recherche.*

Ballard, Robert D., 1975: Dive into the great rift, *National Geographic Magazine* 147(5):604-615.

Ballard, R. D., W. B. Bryan, J. R. Heirtzler, G. Keller, J. G. Moore, Tj. van Andel, Manned submersible observations in the FAMOUS area Mid-Atlantic Ridge, *Science.*

Heirtzler, J. R., 1975: Project FAMOUS: Where the earth turns inside out—Exploring the birthplace of an ocean, *National Geographic Magazine* 147(5):587-603.

Hekinian, R., and M. Hoffert, Rate of palagonitization and manganese coating on basaltic rocks from the rift valley in the Atlantic Ocean near 36°50′ north, *Mar. Geol.*

Keller, George H., Susan H. Anderson, Donald E. Koelsch, and J. William Lavelle, Near bottom currents in the Mid-Atlantic Ridge rift valley, *Canadian J. Earth Sci.*

Koelsch, D. E., and S. H. Anderson, Current meter arrays deployed in the primary dive site selected for Project FAMOUS, *Woods Hole Oceanogr. Inst. Tech. Rep.*

Laughton, A. S., and J. S. M. Rusby, 1975: Long range sonar and photographic studies of the median valley in the FAMOUS area of the Mid-Atlantic Ridge near 37°N, *Deep-Sea Res.* 22(5):279-298.

Macdonald, Kenneth, Bruce P. Luyendyk, John D. Mudie, and F. N. Spiess, A near-bottom geophysical study of the Mid-Atlantic Ridge median valley near 37°N, preliminary observations, *Geology.*

Sediment seen from submersbile craft during project FAMOUS.

Phillips, J. D., H. S. Fleming, R. Feden, W. E. King, and R. Perry, Aeromagnetic study of the Mid-Atlantic Ridge near the Oceanographer Fracture Zone, *Geol. Soc. Amer. Bull.*

Schilling, J. G., 1975: Azores mantle blob: Rare-earth evidence, *Earth Planet. Sci. Lett.* 25(2):103-115.

Storzer, Dieter, and Madeleine Selo, GEOCHRONOLOGIE.—Ages par la methods des traces de fission de basalts preleves dans la valee axiale de la dorsale medio-atlantique aux environs de 37°N, Comfte render de l academie des Sciences, Paris.

Whitmarsh, R. B. Axial Intrusion Zone Beneath the Median Valley of the Mid-Atlantic Ridge at 37°N Detected by Explosion Seismology. *Geophys. J.*

Manganese Nodule Study

The Inter-University Program of Research on Ferromanganese Deposits of the Ocean Floor was initiated at the Arden House Conference/Workshop, which took place January 20-22, 1972, at Lamont-Doherty Geological Observatory. Following the conference, a coordinator's office was set up at Lamont-Doherty Geological Observatory of Columbia University, under NSF Grant GX-33616, to manage the program. Through contact with other participants, the coordinator's office assembled a series of formal proposals by 22 investigators from 13 institutions. This inter-institutional proposal was submitted to the Seabed Assessment Program of IDOE in March, 1972, through Columbia University. The program was funded by the National Science Foundation under GX-34659 for the period July 1 to December 31, 1972. This activity has been termed "Phase I" of the ferromanganese research program and represents a baseline study of our current state of knowledge of manganese nodules on the ocean floor. Most of the reports resulting from this research program were presented in the Phase I Report.

During 1973, the Phase I Report was printed and a Scientific Council was established to guide the program. The Council functioned also in a proposal screening capacity reviewing 40 original proposals, 14 of which were finally submitted to the National Science Foundation for funding. Several technical reports and conference proceedings were printed. Funding of the 14 approved Phase II proposals commenced in the early spring of 1974, and the program then began to accelerate. Two cruises were conducted in summer 1974, during which much sample material and data were collected. Distribution of samples has begun. Most program investigators have received material on which to begin their work.

International cooperation has been an important aspect of the program since its inception. Attendance at the conferences the program has sponsored has been marked by international participation. In 1973 there was direct scientific cooperation by several U.S. program participants and Dr. Geoffrey P. Glasby of the New Zealand Oceanographic Institute. There have been valuable exchanges with the West German VALDIVIA Manganese Exploration Group, which cosponsored a symposium in Hawaii in the summer of 1973. In 1974 there was international participation in sea-going activities. Much of the equipment used on program cruises was made available from industry and government, both foreign and domestic. In particular, the program is indebted to Kennecott Exploration Inc., Ocean Resources Inc. (representing an international consortium), the West German VALDIVIA Group and the French CNEXO.

The Inter-University Program of Research on Ferromanganese Deposits of the Ocean Floor will extend from April 1 to December 31, 1975. Institutions that will participate are: Hawaii Institute of Geophysics (University of Hawaii), Lamont-Doherty Geological Observatory, Massachusetts Institute of Technology, University of Michigan, University of Rhode Island, Scripps Institution of Oceanography, University of Southern California, University of Washington, Washington State University, and University of Wisconsin.

The specific aims of the Seabed Assessment Program limit the Manganese Nodule Project investigations to ferromanganese deposits that can be considered a mineral resource—deposits that have a sufficiently high content of copper, nickel, and/or cobalt to be considered potential ores. Thus constrained, the program is defined by two major questions:

1) What processes are responsible for incorporation of exceptionally high concentrations of copper, nickel, and cobalt in ferromanganese nodules in certain limited regions? and

2) What controls the areal density of nodules, especially in regions where nodules have a high copper-nickel content?

Investigations must include the mode of nodule formation and conditions that determine the density and grade of the nodules at the sediment surface. It is known that in the northern equatorial Pacific significant variations in area density of nodules occur over small distances, in the range of meters to kilometers. Questions to be resolved by the study include:

1) What are the phase assemblages and what is the crystal chemistry of nodules?

2) Can the growth history of nodules be deduced from internal structures and textures?

3) What is the relationship between benthic biota and nodules?

4) What is the role of sediment pore water in determining the geochemistry of ferromanganese nodules and dispersed ferromanganese oxides?

5) What is the rate of growth of the nodules, the accumulation of sediment, and the relative rates of incorporation of the component elements?

6) How do slow-growing nodules remain on top of rapidly accumulating sediment?

7) What are the critical interactions between the nodules and the sediment substrate?

8) How does ocean bottom water influence the formation and development of ferro-manganese nodules?

9) How does water column chemistry affect the occurrence, distribution, and geochemistry of ferromanganese nodules on the sea-floor?

10) How do sea-floor topography and structure influence growth and distribution of ferromanganese nodules?

Manganese Nodule Project Publications

Technical Report No. 1, NSF GX-33616, IDOE-NSF, 1972. Ferromanganese deposits of the North Pacific, by D. R. Horn, B. M. Horn, and M. N. Delach.

Technical Report No. 2, NSF GX-34659, IDOE-NSF, 1972. Worldwide distribution of ferromanganese nodules, compiled from the Scripps Institution of Oceanography Sediment Data Bank, by J. Z. Frazer and G. Arrhenius.

Technical Report No. 3, NSF GX-33616, IDOE-NSF, 1973. Metal content of ferromanganese deposits of the oceans, by D. R. Horn, M. N. Delach, and B. M. Horn.

Technical Report No. 4, NSF GX-33616, IDOE-NSF, 1973. Ocean Manganese Nodules: Metal values and mining sites, by D. R. Horn, B. M. Horn, and M. N. Delach.

Technical Report No. 5, NSF GX-34659, IDOE-NSF, 1973. Hawaii Institute of Geophysics data banks for manganese collections and hydration rind dating, by J. E. Andrews and C. W. Landmesser.

Technical Report No. 7, IDOE-NSF, 1974. Manganese nodule mineralogy and geochemistry methods, workshop, Battelle Seattle Research Center, June 14-15, 1973.

Technical Report No. 8, NSF GX-33616, IDOE-NSF, 1973. Factors which control the distribution of ferromanganese nodules and proposed research vessel's track, North Pacific, Phase II, Ferromanganese Program, by D. R. Horn, B. M. Horn, and M. N. Delach.

Papers from a conference on ferromanganese deposits on the ocean floor, D. R. Horn (ed.), Arden House, Harriman, N. Y. and Lamont-Doherty Geological Observatory of Columbia University, Palisades, N.Y., January 20-22, 1972, 293 pp., IDOE-NSF, 1973.

Manganese nodule deposits in the Pacific, Symposium/Workshop Proc. Honolulu, Hawaii, October 16-17, 1972, State Center for Science Policy and Technology Assessment, Department of Planning and Economic Development, State of Hawaii, 220 pp., 1973.

Phase I report: Inter-University Program of Research on Ferromanganese Deposits of the Ocean Floor, sponsored by Seabed Assessment Program of IDOE-NSF, April 1973, 198 pp., unpublished.

Papers on the origin and distribution of manganese nodules in the Pacific and prospects for exploration, M. Morgenstein (ed.), Hawaii Institute of Geophysics, University of Hawaii, 256 pp. June 1973.

Manganese Nodule Study References

Amos, Anthony F., Robert D. Gerard, Thomas C. Malone, Christopher Garside, Sidney Levitus, Allen Z. Paul, and Oswald A. Roels, 1973: Study of the impact of manganese nodule mining on the seabed and water column, in Phase I Report: Inter-University Program of Research on Ferromanganese Deposits of the Ocean Floor, sponsored by Seabed Assessment Program of IDOE-NSF, April, 1973, pp. 221-264.

Amos, A. F., S. C. Danbin, Jr., C. Garside, T. C. Malone, A. Z. Paul, G. E. Rice, and O. A. Roels, 1974: The environmental impact of manganese-nodule mining: Preliminary report on a cruise to study baseline conditions in a manganese nodule province, *2nd Int. Colloq. Exploit. Oceans,* Bordeaux, France, October 1-4, 1974, Vol. 5, 20 pp.

Andrews, James E., 1971: Abyssal hills as evidence of transcurrent faulting on North Pacific Fracture Zones, *Geol. Soc. Amer. Bull.* 82(2):463-470.

Andrews, J. E., and M. A. Meylan, 1972: Results of bottom photography: Kana Keoki cruise manganese '72, in Investigations of ferromanganese deposits from the Central Pacific, by J. Andrews, M. Morgenstein, C. Fein, M. Meyland, S. Margolis, G. Andermann, and G. P. Glasby, *Hawaii Insti. Geophy. Rep.* HIG 72-23, pp. 83-111.

Arrhenius, G. 1952: Sediment cores from the East Pacific, *Rep. Swedish Deep-Sea Exped.,* Vol. 5, H. Pettersson (ed.), Goteborg, Sweden.

Bezrukov, P. L., 1972: On the sedimentation in the northern part of the South Pacific, *Proc. UNESCO Int. Symp. Oceanogr.* South Pacific, Wellington.

Burns, Virginia M., and Roger G. Burns, 1973: Manganese nodule authigenesis: Mechanism for nucleation and growth, *Geol. Soc. Amer. Abstr. with Programs* 5(7): 564.

Burns, R. G. and V. M. Burns, 1974: Mineralogy of ferromanganese nodules. Chapter 7 in *Marine Manganese Deposits, G. P. Glasby* (ed.), Elsevier, pp. xxx-xxx.

Burns, Roger G., and Virginia M. Burns, 1974. The uptake of cobalt by ferromanganese nodules, soils, and manganese (IV) oxide (Abstract), *EOS, Trans. Amer. Geophys. Union* 55(12):1139.

Burns, Roger G., Virginia M. Burns, Windsor Sung, and Bruce A. Brown, 1974: Ferromanganese nodule mineralogy: Suggested terminology of the principal manganese oxide phases, *Geol. Soc. Amer. Abstr. with Programs* 6(7): 1029-1031.

Cherdyntsev, V. V., N. B. Kadyrov, and N. Novichkova, 1971: Origin of manganese nodule of the Pacific Ocean from radioisotope data, *Geokhimiya* 3:339-354.

Fewkes, Ronald H., 1973: External and internal features of marine manganese nodules as seen with the SEM and their implications in nodule origin, in Papers on the origin and distribution of manganese nodules in the Pacific and prospects for exploration, Maury Morgenstein (ed.), Hawaii Institute of Geophysics, University of Hawaii, Honolulu, pp. 21-29.

Fewkes, R. H., R. K. Sorem, and D. Banning, 1974: Copper-nickel-rich segregations in manganese nodules from the Pacific Ocean (Abstract), *EOS, Trans. Amer. Geophys. Union* 55(12):1139, 1974:

Glasby, G. P., 1973: The role of submarine volcanism in controlling the genesis of marine manganese nodules, *Oceanogr. Mar. Biol. Annual Rev.* 11:27-44.

Greenslate, J. L. 1974: Microorganisms participate in the construction of manganese nodules, *Nature* 219:358-359.

Greenslate, J. L. 1974: Manganese and biotic debris associations in some deep-sea sediment, *Science* 186:529-531.

Greenslate, J. L., J. Z. Frazer, and G. Arrhenius, 1973: Origin and deposition of selected transition elements in the seabed, in *Papers on the origin and distribution of manganese nodules in the Pacific and prospects for exploration,* M. Morgenstein (ed.), Hawaii Institute of Geophysics, University of Hawaii, Honolulu, pp. 45-69.

Greenslate, J., R. R. Hessler, and H. Thiel, 1974: Manganese nodules are alive and well on the sea floor, in National needs and ocean solutions, *Proc. Tenth Annual Conf. Mar. Tech. Soc.,* Washington, D.C., pp. 171-181.

Heye, D., and H. Beiersdorf, 1973: Radioaktive und magnetische Untersuchungen an Manganknollen zur Ermittlung der Wachstumsgeshwindigkeit bzw zur Altersbestimmung, *Zeitschrift für Geophysik* 39:703-726.

Johnson, D. A., 1971: Studies of deep-sea erosion using deep-towed instruments, Ph.D. thesis, University of California, San Diego.

Lalou, C., E. Brichet, and M. J. Wyart, 1972: Signification des mesures radiochimiques dans l'evaluation de la vitesse de croissance des nodules de manganese, Comptes Rendus Acad. Sc., Paris. 272 (Series D): 815-818.

Luyendyk, Bruce P., 1970: Origin and history of abyssal hills in the northeast Pacific Ocean, *Geol. Soc. Amer. Bull.* 81: 2237-2260.

Margolis, Stanley V., and Geoffry P. Glasby, 1973: Microlaminations in marine manganese nodules as revealed by scanning electron microscopy, *Geol. Soc. Amer. Bull.* 84(11): 3601-3609.

Piper, D. Z., 1974: Rare earth elements in ferromanganese nodules and other marine phases, *Geochim. Cosmochim. Acta* 38:1007-1022.

Roels, A. A., A. F. Amos, O. R. Anderson, C. Garside, K. C. Haines, T. C. Malone, A. Z. Paul, and G. E. Rice, 1973: The environmental impact of deep-sea mining: Progress report, *NOAA Tech. Rep. ERL* 29-OD-11, U.S. Department of Commerce, Boulder, Colo. 80302, 180 pp.

Sorem, R. K., 1973: Manganese nodules as indicators of long-term variations in sea-floor environments, in *Papers on the origin and distribution of manganese nodules in the Pacific and prospects for exploration*, Maury Morgenstein (ed.), Hawaii Institute of Geophysics, University of Hawaii, Honolulu, pp. 151-164.

Sorem, R. K., and R. H. Fewkes, 1974: Internal characteristics of marine manganese nodules, in *Marine Manganese Deposits*, G. P. Glasby (ed.), Elsevier.

Woo, C. C., 1973: Scanning electron micrographs of marine manganese micronodules, marine pebble-sized nodules and fresh-water manganese nodules, in *Papers on the origin and distribution of manganese nodules, in the Pacific and prospects for explaration*, Maury Morgenstein (ed.), Hawaii Institute of Geophysics, University of Hawaii, Honolulu, pp. 165-171.

Living Resources Program

The main goal of this program is to provide the scientific basis for improved management and use of the ocean's living resources. Emphasis is on interdisciplinary studies of the mechanisms that produce and sustain marine life.

Coastal Upwelling Ecosystems Analysis (CUEA)

This 7-year program to investigate the complex physical and biological processes in coastal upwelling ecosystems includes 20 NSF-IDOE funded projects (table 8). More than 40 ocean scientists are participating in the program. Preliminary field studies included MESCAL I and II, primarily biological studies made off the coast of Baja California during March 1972 and March and April 1973, and CUE (Coastal Upwelling Experiment) I and II, physical oceanographic studies made off the Oregon coast during April through October 1972 and the summer of 1973.

JOINT-I and JOINT-II

The first integrated biological and physical field studies were those of JOINT-I off the northwest coast of Africa during spring and summer 1974. U.S. vessels operated in the JOINT-I area during the period March through May 1974. Early results show this part of the African coast to be a major upwelling area.

JOINT-II is planned as an intensive international study of the Peruvian upwelling ecosystem between 1975 and 1977. Studies of satellite-imagery, remote-sensing, and hydrographic-transect data are underway. Nutrient productivity, chlorophyll, and other data are being collected over a large area of the Equatorial and Southwest Pacific Ocean as part of the El Niño Watch cruises—see North Pacific Experiment (NORPAX). An intensive period of field experiments in 1976 and 1977 is being planned by scientists from Chile, Columbia, Ecuador, Peru, France, the Federal Republic of Germany, Spain, and the United States. Observations will be made from vessels and shore stations, as well as satellites and aircraft during the following periods: March and April 1976, July to October 1976, and March to May 1977. The last experimental period will be a major multiship effort. Representatives of these nations are collaborating with the planning directorate of the International ERFEN project (Regional Study of the El Niño phenomenon). The accompanying summaries identify CUEA data submitted to NOAA Environmental Data Service's National Oceanographic Data Center.

NODC Accession No.: 75-0531
Organization: University of Miami, Rosenstiel School of Marine and Atmospheric Science
Investigator: C. N. K. Mooers
Grant No.: GX-31264

CUEA data collected off the Oregon coast are available on one magnetic tape, and in data reports, as follows:

(A) 122 STD casts (discrete and time-series) and 57 bottle casts (discrete and time-series) from Cruises of the RV CAYUSE, C7208-F1 and F2, 15-19 August and 21-25 August, 1972.
Data report: *Coastal Upwelling Experiment-I Hydrographic Data Report*, University of Miami, RSMAS No. 74003. Available from U.S. Department of Commerce, National Technical Information Service, Springfield, Va. 22151 (Accession No. PB 235927/AS).

(B) 334 profiles from profiling current meters from cruises of RV YAQUINA, Y7207-E, 31 July to 7 August, 1972, and RV CAYUSE, C7208-F1 and F2, 15-19 August and 21-25 August, 1972.
Data report: *Coastal Upwelling Experiment-I Profiling Current Meter Report*, University of Miami, RSMAS No. 74015. Available from U.S. Department of Commerce, National Technical Information Service, Springfield, Va. 22151 (Accession No. PB 235933/AS).

NODC Accession No.: 74-00726
Organization: NOAA Pacific Marine Environmental Laboratory
Investigator: D. Halpern
Grant No.: AG-299

CUEA data on two magnetic tapes contain 1,234 STD stations obtained by NOAA's OSS OCEANOGRAPHER during Coastal Upwelling Experiments I and II.
Data report: *Coastal Upwelling Ecosystems Analysis—STD Measurements off the Oregon Coast, July/August 1972*, David Halpern, James R. Holbrook—Data Report 4. Available from U.S. Department of Commerce, National Technical Information Service, Springfield, Va. 22151 (Accession No. PB 232375/AS).

NODC Accession No.: 75-0532
Organization: CUEA Data Analysis Group, University of Washington
Investigator: Various CUEA participants

Table 8.—U.S. institutions, investigators, and projects in CUEA program

Organization	Investigator	Project title
University of California, Scripps Institution of Oceanography	M. Blackburn	Behavior and Biology of Nekton
University of Connecticut	R. W. Garvine	Theoretical Studies of Physical Dynamics
Duke University	R. T. Barber	Primary Production, Chelation and Toxicity
Florida State University	Y. Hsueh	Development of Diagnostic Models of Coastal Upwelling
	J. J. O'Brien	Simulation of Time-Dependent Circulation
	D. W. Stuart	Meteorological Research in the CUE-II and JOINT-I Experiments
Inter-American Tropical Tuna Commission	M. Stevenson	LaGrangian Measurements of Currents in the Coastal Upwelling Zone with Drogues
University of Miami	C. N. K. Mooers	Physical Dynamics of the Frontal Zone
	J. C. Van Leer	Cyclesonde Measurements of the Frontal Zone
NOAA Pacific Marine Environmental Laboratory	D. Halpern	Near-Surface Circulation Studies in a Coastal Upwelling Environment
Oregon State University	R. Smith D. Pillsbury	Mesoscale, Descriptive Physical Oceanography
	J. S. Allen	Analytical, Numerical Studies of Processes
University of Rhode Island	T. J. Smayda	Phytoplankton Species, Succession, Sinking
University of Washington	R. C. Dugdale	Kinetics of Nutrient Uptake
	J. C. Kelley	Nutrient and Phytoplankton Fields
	T. T. Packard	Enzymatic Determination of Transformations
	R. Thorne O. Mathiesen	Acoustic Assessment and Modelling of Nekton
	J. J. Walsh	Systems Model of Upwelling Ecosystems
	T. Whitledge	Nutrient Regeneration and Excretion
Woods Hole Oceanographic Institution	G. T. Rowe K. Smith	Nutrient Cycles and the Benthos

(A) CUEA data on six magnetic tapes containing 478 CTD stations (casts) from Coastal Upwelling Experiment-I (1972) collected by RV YAQUINA, cruise numbers Y7206-C, Y7207-A, Y7207-B, Y7207-E, Y7208-C, and Y208-E.

(B) CUEA data on two magnetic tapes containing 289 CTD stations (casts) from Coastal Upwelling Experiment-II (1973) collected by RV YAQUINA, cruise numbers Y7306-E, Y7307-A, Y7308-A, and Y7308-B.

CUEA Bibliography

*Curtin, T. B., and C. N. K. Mooers, 1974: Coastal upwelling experiment-I hydrographic data report, RV CAYUSE cruises C7208-F1 and F2, 15-19 August and 21-25 August 1972, University of Miami, Rosenstiel School of Marine and Atmospheric Science, 69 pp., UM-RSMAS #74003.

*Curtin, T. B., and C. N. K. Mooers, 1974: Coastal upwelling experiment-I, profiling current meter data report, RV YAQUINA cruise Y7207-E, 31 July-August 1972, RV CAYUSE cruises C7208-F1 and F2, 15-19 August and 21-25 August 1972, University of Miami, Rosenstiel School of Marine and Atmospheric Science, 123 pp., UM-RSMAS #74015.

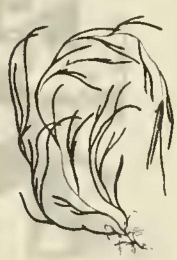
*Curtin, T. B., and C. N. K. Mooers, 1974. Coastal upwelling experiment-I and II, surface hydrographic fields data report, University of Miami, Rosenstiel School of Marine and Atmospheric Science, 94 pp., UM-RSMAS #74026.

Curtin, T. B., W. R. Johnson, and C. N. K. Mooers, 1975: Coastal upwelling experiment-II, hydrographic data report RV YAQUINA cruises 47307-A and Y7308-B, 15-18 July and 16-20 August 1973, RV CAYUSE cruise C7308-E, 18-31 August 1973, University of Miami, Rosenstiel School of Marine and Atmospheric Science, 100 pp., UM-RSMAS #75003.

Halpern, David, R. Dale Pillsbury, and Robert L. Smith, 1974: An intercomparison of three current meters operated in shallow water, *Deep-Sea Res.* 21:489-497.

Halpern, David, 1974: Observations of the deepening of the wind-mixed layer in the Northeast Pacific Ocean, *J. Phys. Oceanogr.* 4(3):454-466.

[1] These reports may be obtained from the National Technical Information Service, Springfield, Virginia 22151



Seagrass Ecosystem Study (SES)

This study was begun in July 1974 to provide information about the benthic marine ecosystem, particularly the dynamic processes by which seagrass ecosystems are maintained, their extent, and their contribution to the total marine ecosystem.

Several factors have made the need for these studies clear: (1) the increased awareness of the importance of nearshore waters in the productivity of the oceans, coupled with the increased awareness of the vulnerability of nearshore waters to human activities; (2) the increased emphasis marine biologists are placing on nearshore renewable resources; and (3) the identification of seagrass ecosystems as a next phase of needed research by the recently completed International Biological Program (IBP).

The SES program will formulate models to evaluate ecosystem theories, help design experiments, carry on specific experiments, and coordinate the research at national and international levels. The first projects will emphasize (1) identification of critical biological processes in seagrass ecosystems and (2) assessment of the importance of seagrass ecosystems. As the program progresses, emphasis will be on improved models and prediction of processes. The ultimate goal will be to learn how these systems are maintained and interact with other systems over long periods of time. The program (fig. 13) consists of three phases: Seagrass One—Pilot studies on critical biological processes, including laboratory culture and transplanting experiments; Seagrass Two—Studies of seagrass ecosystems that are readily accessible to participating scientists; and Seagrass Three—Intensive studies at selected sites, representing ecosystem types and bringing together researchers from this and other countries. Participants in the SES program are identified in table 9.

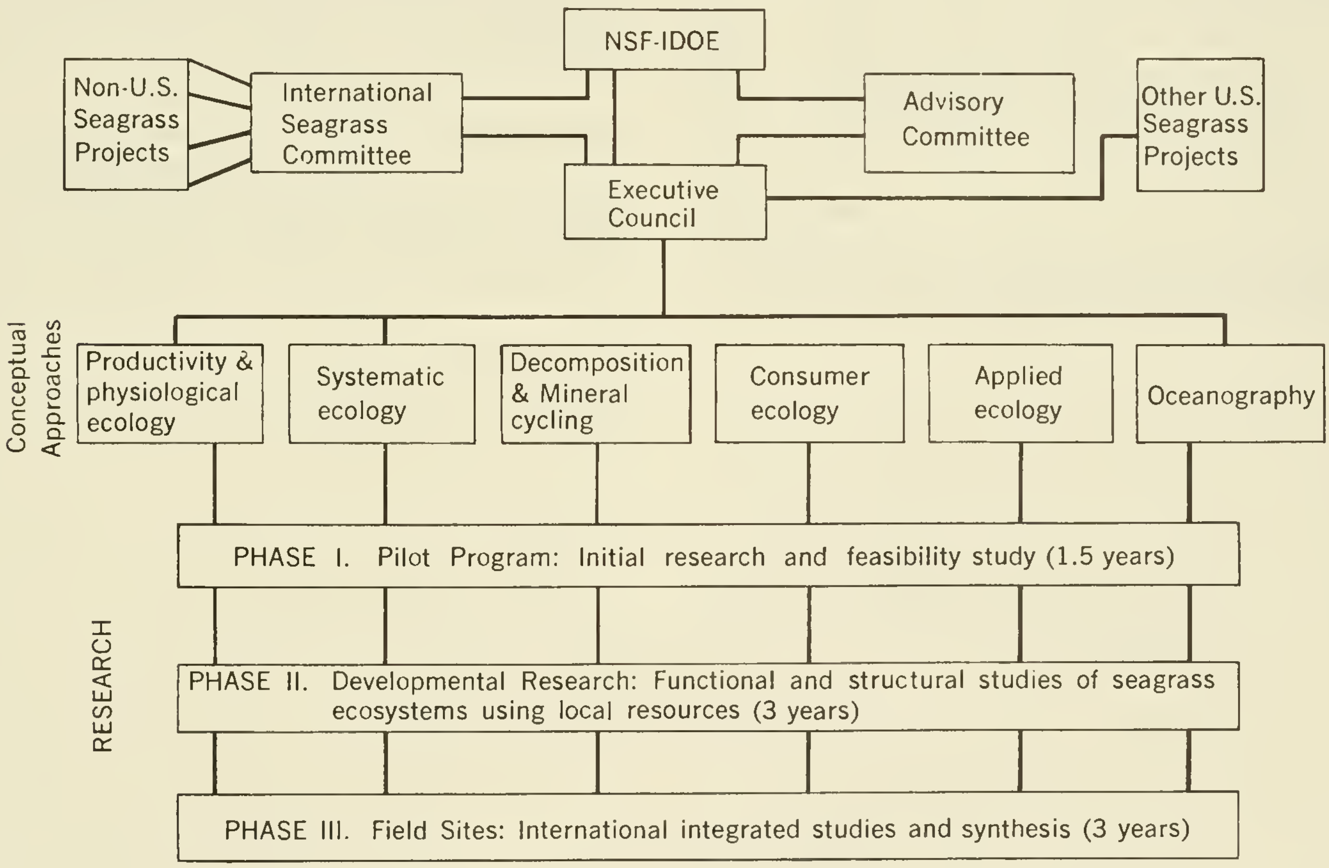


Figure 13.—Program structure of Seagrass Ecosystem Study.

Seagrass One consists of five research projects:

1. Man's Use of the Seagrass Ecosystem: Identification and documentation of the contribution of seagrass ecosystems to other food webs, especially those of direct importance to humans, and to other direct human values of seagrasses such as coastline stabilization (University of Alaska).

2. Distribution of Seagrass Ecosystems: Collection and analysis of current information on distribution of seagrasses and associated species in relation to patterns related to environmental conditions and perturbation (University of Hawaii).

3. The Production and Decomposition of Seagrasses: Analysis of the producer-decomposer regulation including photosynthesis, respiration, and secretion of dissolved organics and their transfer to other organisms (Michigan State University).

4. Environmental Tolerances of Seagrasses: Physiological investigation of the environmental tolerance limits of seagrasses that determine the conditions under which the plants can grow (University of Texas).

5. Phenology and Transplanting of Seagrasses: Implementation of a worldwide system for providing knowledge on the periodicity of events in the life history of seagrasses, especially as related to climate and the start of long-term transplant experiments (Seattle Pacific College).

The field program will consist of intensive studies at several sites representing biogeographic zones where seagrass ecosystems exist: the subarctic, the temperate, tropical, and subtropical as well as stress conditions where pollution is a major problem.

Table 9.—Participants in Seagrass Ecosystem Study

International Seagrass Committee
- Robert G. Wetzel (U.S.) Chairman
- C. Peter McRoy (U.S.)
- Patrick L. Parker (U.S.)
- Tom Fenchel (Denmark)
- C. den Hartog (The Netherlands)
- Akihiko Hattori (Japan)
- J. M. Peres (France)

Seagrass One

Executive Council:
- C. Peter McRoy, *Program Director*, University of Alaska
- K. W. Bridges, University of Hawaii
- Patrick L. Parker, University of Texas

Project Coordinator:
- Carla Helfferich

Advisory Committee:
- Dieter Mueller-Dumbois, University of Hawaii
- Norbert Untersteiner, University of Washington
- David W. Menzel, University of Georgia

Participants:
- C. Peter McRoy, University of Alaska
- K. W. Bridges, University of Hawaii
- Michael J. Klug, Michigan State University
- Robert G. Wetzel, Michigan State University
- Calvin McMillan, University of Texas
- Ronald C. Phillips, Seattle Pacific College
- J. C. Zieman, University of Virginia
- John Ogden, Fairleigh Dickinson University

Appendix—NAMDI and ROSCOP Summaries

In the following NAMDI (National Marine Data Inventory) and ROSCOP (Report of Observations/Samples Collected by Oceanographic Programs) summaries,* all institutions or activities are U.S. participants in IDOE and all projects are part of the Declared National Program (DNP) for Marine Data Exchange. All IDOE-related NAMDIs and ROSCOPs received by NOAA's Environmental Data Service from May 1974 to April 1975 are included in this appendix. The 95 reported NAMDIs and ROSCOPs bring the IDOE 1970-75 total to 311. Information is presented in the following order.

Line 1: Institution of IDOE grant holder as identified in List of Abbreviations; platform or vessel used to collect data; cruise number and leg, where applicable; cruise period and number of days.

Line 2: NODC record number (reference to this number when requesting NAMDIs and ROSCOPs facilitates retrieval of the information); general geographic area.

Line 3: Chief scientist(s); supporting organization(s) indicated in parentheses, as identified in List of Abbreviations; and Marsden Square(s) as shown by charts following Appendix.

Line 4: Grant Number (NSF reference); program or subprogram as indicated in text.

A listing of parameters and the number of stations, samples, or miles of record follows. A dash indicates continuously sampled, not reported, or that a number would not be meaningful.

LIST OF ABBREVIATIONS

Institution of IDOE Grant Holder**

DUKE	Duke University
NOAA	National Oceanic and Atmospheric Administration
NMFS	National Marine Fisheries Service, NOAA
PMEL	Pacific Marine Environmental Laboratory, NOAA (formerly the Pacific Oceanographic Laboratory)
SKIO	Skidaway Institute of Oceanography
SIO	Scripps Institution of Oceanography
TAMU	Texas A & M University
URI	University of Rhode Island
UW	University of Washington
WHOI	Woods Hole Oceanographic Institution

Organizations providing support:

NSF IDOE	National Science Foundation—International Decade of Ocean Exploration program
ONR	Office of Naval Research
EPA	Environmental Protection Agency
AEC	Atomic Energy Commission

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* See Introduction.

** Certain cooperative data collection efforts were performed on vessels other than those of the grant holder's parent institution, and certain inventory forms were submitted by other institutions.

Environmental Quality Program

Geochemical Ocean Sections (GEOSECS) Study

1. WHOI ATLANTIS II Cruise 83, Leg 1, June 1974, 18 days
2. NODC Record No. R390320, Central Atlantic
3. Katz, E. (NSF IDOE/ONR/NOAA) Marsden Squares 2, 3, 301, 302
4. NSF Grant No. GX-28161, GOESECS/GATE/GARP

Chemical oceanography: dissolved and particulate iodate 74 (GATE/GARP parameters are not listed.)

1. WHOI ATLANTIS II Cruise 83, Leg 2, July 1974, 16 days
2. NODC Record No. R390321, Central Atlantic
3. Katz, E. (NSF IDOE/ONR/NOAA) Marsden Squares 3, 4, 302, 303
4. NSF Grant No. GX-28161, GEOSECS/GATE/GARP

Chemical oceanography: dissolved and particulate iodate 46 (GATE/GARP parameters are not listed.)

Pollutant Transfer Studies

1. DUKE EASTWARD Cruise E-3-74, April 1974, 6 days
2. NODC Record No. 09040, Northeast Atlantic
3. Atkinson, L. (NSF IDOE/EPA) Marsden Squares 81, 116
4. NSF Grant No. GX-33615, pollutant transfer

Chemical oceanography: trace elements 20

1. WHOI ATLANTIS II Cruise 85, Leg 2, August-September 1974, 30 days
2. NODC Record No. 09130, North Atlantic
3. Farrington, J. (NSF IDOE/ONR) Marsden Squares 113, 114
4. NSF Grant No. GX-33777, atmospheric pollutant transfer and deposition

Physical oceanography: mechanical bathythermograph 5, surface temperature—
Chemical oceanography: oxygen 5, trace elements 1
Geology/Geophysics: seismic reflection profiles (miles) 1500, engineering properties of sea floor 2, bottom photography 1, organic geochemical measurements in cores and water 5, chemical and physical analysis of sediments
Biology: particulate organic matter 5
Pollution: tar in surface water 6

Biological Effects Studies

1. TAMU GYRE Cruise 4-G-8, Leg 1, May 1974, 7 days
2. NODC Record No. 08886, Gulf of Mexico
3. Sackett, W. (NSF IDOE) Marsden Squares 81, 82
4. NSF Grant No. GX-37344, biological effects

Physical oceanography: classical oceanographic stations 1
Geology/Geophysics: dredge 1, grab 9, core 17, bathymetry—wide beam (miles) 200
Biology: zooplankton 3

1. TAMU GYRE Cruise 74-G-9, May-June 1974, 10 days
2. NODC Record No. 08951, Gulf of Mexico
3. Presley, B. (NSF IDOE) Marsden Squares 81, 82
4. NSF Grant No. GX-37347, biological effects

Physical oceanography: classical oceanographic stations 41, surface temperature 41
Chemical oceanography: oxygen 41, phosphates 41, trace elements 41, suspended matter 41
Geology/Geophysics: core 6, grab 10, interstitial water 2
Biology: particulate organic matter 41, phytoplankton 8, zooplankton 8

Controlled Ecosystem Pollution Experiment (CEPEX)

1. SKIO (small boat) May 1974, 31 days
2. NODC Record No. 08891, Northeast Pacific (Vancouver I.)
3. Menze, D. (NSF IDOE) Marsden Square 157
4. NSF Grant No. GX-39148, CEPEX

Physical oceanography: classical oceanographic stations 17, vertical profiles (STD/CTD) 17, light penetration 17, particle size spectrum 17
Chemical oceanography: oxygen 6, phosphates 6, nitrates 17, nitrites 6, alkalinity 6, silicates 6
Biology: primary productivity 15, phytoplankton pigments 17, phytoplankton 17, zooplankton 17

1. SKIO (experimental enclosure) June 1974, 30 days
2. NODC Record No. 08939, Northeast Pacific (Vancouver I.)
3. Menzel, D. (NSF IDOE) Marsden Square 157
4. NSF Grant No. GX-39148, CEPEX

Physical oceanography: classical oceanographic stations 8, vertical profiles (STD/CTD) 8, light penetration 8
Chemical oceanography: oxygen 4, particulate-P 8, phosphates 4, nitrates 9, nitrites 4, trace elements 8, alkalinity 8, silicates 4
Biology: primary productivity 8, phytoplankton pigments 8, particulate organic matter 8, dissolved organic carbon 4, bacteria and other microorganisms 8, phytoplankton 8, zooplankton 8 (experimental data only)

1. WHOI KNORR Cruise 38, Leg 2, March-April 1974, 12 days
2. NODC Record No. 08903, North Atlantic
3. Scheltma, R. (NSF IDOE) Marsden Squares 115, 116, 152
4. NSF Grant No. GX-39147, CEPEX

Biology: bacteria and other microorganisms 4

Environmental Forecasting Program

Midocean Dynamics Experiment (MODE)

1. URI TRIDENT Cruise 124, September 1972, 10 days
2. NODC Record No. 08840, North Atlantic
3. Sturges, W. (NSF IDOE) Marsden Squares 79, 80
4. NSF Grant No. GX-31340, MODE

Physical oceanography: expendable bathythermograph 35
Dynamics: current meter stations 2, current meter duration (days) 120

1. WHOI TRIDENT Cruise 161, December 1974, 14 days
2. NODC Record No. R390258, North Atlantic
3. Richardson, P. (NSF IDOE, DES/ONR) Marsden Squares 80, 116
4. NSF Grant No.'s IDO75-08765 and DES74-21472, POLYMODE

Meteorology: atmospheric particulate matter—
Physical oceanography: expendable bathythermograph 185
Biology: phytoplankton 5, zooplankton 5

North Pacific Experiment (NORPAX)—POLE

1. SIO WASHINGTON Cruise Tasaday 09, January-February 1974, 24 days
2. NODC Record No. 09100, Central Pacific
3. Knox, R. (NSF IDOE/ONR) Marsden Squares 88, 124
4. NSF Grant No. CA-88, NORPAX POLE

Meteorology: upper air observations 47
Physical oceanography: classical oceanographic stations 78, vertical profiles (STD/CTD) 170, expendable bathythermograph 358, continuous surface temperature recording—, continuous surface salinity recording—
Dynamics: drifters 6, drogues—
Geology/Geophysics: magnetism (miles) 250, bathymetry—wide beam (miles) 700

1. SIO FLIP, January-February 1974, 30 days
2. NODC Record No. 09101, Central Pacific
3. Davis, R. (NSF IDOE/ONR) Marsden Square 124
4. NSF Grant No. CA-88, NORPAX POLE

Meteorology: surface observations—, incident radiation—
Chemical oceanography: oxygen 80
Dynamics: current meter duration (days) 20, instrumented wave recordings—

North Pacific Experiment (NORPAX)—XBT

1. NOAA NMFS CALIFORNIAN Cruise 245, July 1974, 7 days
2. NODC Record No. R390135, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 88, 123, 157, 158, 159
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 34, expendable bathythermograph 34

1. NOAA NMFS CALIFORNIAN Cruise 245, July-August 1974, 6 days
2. NODC Record No. R390136, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 34, expendable bathythermograph 34

1. NOAA NMFS CHEVRON CALIFORNIA Cruise 51, December 1974, 4 days
2. NODC Record No. R390341, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 88, 124, 160, 196
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 15, expendable bathythermograph 15

1. NOAA NMFS CHEVRON CALIFORNIAN Cruise 51, December 1973, 6 days
2. NODC Record No. R390337, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 27, expendable bathythermograph 27

1. NOAA NMFS CHEVRON CALIFORNIA Cruise 52, December 1973, 7 days
2. NODC Record No. R390336, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 86, 87, 88, 120, 121, 122
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 34, expendable bathythermograph 34

1. NOAA NMFS CHEVRON CALIFORNIA Cruise 55, January 1974, 6 days
2. NODC Record No. R390137, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 30, expendable bathythemograph 30

1. NOAA NMFS CHEVRON CALIFORNIA Cruise 55, January 1974, 6 days
2. NODC Record No. R390138, Northeast Pacific
3. McLain, D. (NSF IBOE/ONR) Marsden Squares 88, 124, 160, 196
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 20, expendable bathythermograph 20

1. NOAA NMFS MISSISSIPPI Cruise 29, July 1973, 6 days
2. NODC Record No. R390339, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 88, 124, 160, 196
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 31, expendable bathythermograph 31

1. NOAA NMFS CHEVRON MISSISSIPPI Cruise 36, September-October 1973, 4 days
2. NODC Record No. R390340, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 88, 124, 160, 196
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 25, expendable bathythermograph 25

1. NOAA NMFS EXXON NEWARK Cruise 1, February 1974, 12 days
2. NODC Record No. R390139, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 121, 157, 158, 194, 195, 196
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 14, expendable bathythermograph 14

1. NOAA NMFS HAWAIIAN CITIZEN Cruise 234, December 1973, 16 days
2. NODC Record No. R390338, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 88, 122, 123, 124, 157, 158
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 8, expendable bathythermograph 8

1. NOAA NMFS HAWAIIAN CITIZEN Cruise 234, January 1974, 6 days
2. NODC Record No. R390140, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 88, 123, 124, 157, 158, 159
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 14, expendable bathythermograph 14

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 83, February 1974, 5 days
2. NODC Record No. R390143, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 21, expendable baththermograph 21

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 83, February 1974, 5 days
2. NODC Record No. R390144, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 86, 87, 88, 120, 121, 122
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 24, expendable bathythermograph 24

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 84, February 1974, 5 days
2. NODC Record No. R390145, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 19, expendable bathythermograph 19

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 84, February 1974, 5 days
2. NODC Record No. R390146, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 23, expendable bathythermograph 23

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 85, March 1974, 5 days
2. NODC Record No. R390147, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 21, expendable bathythermograph 21

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 85, March 1974, 5 days
2. NODC Record No. R390148, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 86, 87, 88, 120, 121, 122
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 22, expendable bathythermograph 22

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 86, March 1974, 5 days
2. NODC Record No. R390149, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 22, expendable bathythermograph 22

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 86, March 1974, 6 days
2. NODC Record No. R390150, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 29, expendable bathythermograph 29

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 87, March-April 1974, 5 days
2. NODC Record No. R390151, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 22, expendable bathythermograph 22

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 87, April 1974, 6 days
2. NODC Record No. R390152, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 28, expendable bathythermograph 28

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 88, April 1974, 6 days
2. NODC Record No. R390153, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 21, expendable bathythermograph 21

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 88, April 1974, 6 days
2. NODC Record No. R390154, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 23, expendable bathythermograph 23

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 89, April-May 1974, 5 days
2. NODC Record No. R390155, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 93, expendable bathythermograph 93

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 89, May 1974, 5 days
2. NODC Record No. R390156, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 86, 87, 88, 120, 121, 122
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 105, expendable bathythermograph 105

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 90, May 1974, 5 days
2. NODC Record No. R390157, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 21, expendable bathythermograph 21

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 90, May 1974, 5 days
2. NODC Record No. R390158, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 22, expendable bathythermograph 22

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 91, May 1974, 5 days
2. NODC Record No. R390159, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88. 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 22, expendable bathythermograph 22

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 91, June 1974, 4 days
2. NODC Record No. R390160, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 21, expendable bathythermograph 21

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 92, June 1974, 4 days
2. NODC Record No. R390161, Northeast Pacific

3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 50, expendable bathythermograph 50

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 92, June 1974, 4 days
2. NODC Record No. R390162, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 53, expendable bathythermograph 53

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 93, June 1974, 4 days
2. NODC Record No. R390163, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 23, expendable bathythermograph 23

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 93, June-July 1974, 5 days
2. NODC Record No. R390164, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 23, expendable bathythermograph 23

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 94, July 1974, 4 days
2. NODC Record No. R390165, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 21, expendable bathythermograph 21

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 94, July 1974, 5 days
2. NODC Record No. R390166, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 86, 87, 88, 120, 121, 122
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 25, expendable bathythermograph 25

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 95, July 1974, 5 days
2. NODC Record No. R390167, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 23, expendable bathythermograph 23

1. NOAA NMFS HAWAIIAN ENTERPRISE Cruise 95, July 1974, 4 days
2. NODC Record No. R390168, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 23, expendable bathythermograph 23

1. NOAA NMFS HAWAIIAN QUEEN Cruise 138, March 1974, 7 days
2. NODC Record No. R390169, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 88, 123, 124, 157, 158, 159
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 18, expendable bathythermograph 18

1. NOAA NMFS HAWAIIAN QUEEN Cruise 140, April 1974, 7 days
2. NODC Record No. R390170, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 15, expendable bathythermograph 15

1. NOAA NMFS HAWAIIAN QUEEN Cruise 140, May 1974, 5 days
2. NODC Record No. R390171, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 26, expendable bathythermograph 26

1. NOAA NMFS HAWAIIAN QUEEN Cruise 141, May 1974, 7 days
2. NODC Record No. R390172, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 88, 123, 124, 157, 158, 159
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 66, expendable bathythermograph 66

1. NOAA NMFS HAWAIIAN QUEEN Cruise 141, May 1974, 7 days
2. NODC Record No. R390173, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 35, expendable bathythermograph 35

1. NOAA NMFS HAWAIIAN QUEEN Cruise 142, June 1974, 4 days
2. NODC Record No. R390174, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 86, 87, 88, 120, 121, 122
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 22, expendable bathythermograph 22

1. NOAA NMFS HAWAIIAN QUEEN Cruise 142, June 1974, 6 days
2. NODC Record No. R390175, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 33, expendable bathythermograph 33

1. NOAA NMFS HAWAIIAN QUEEN Cruise 143, June 1974, 7 days
2. NODC Record No. R390176, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 86, 87, 88, 120, 121, 122
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 31, expendable bathythermograph 31

1. NOAA NMFS HAWAIIAN QUEEN Cruise 143, July 1974, 6 days
2. NODC Record No. R390177, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 32, expendable bathythermograph 32

1. NOAA NMFS HAWAIIAN QUEEN Cruise 144, July 1974, 7 days
2. NODC Record No. R390178, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 86, 87, 88, 120, 121, 122
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 33, expendable bathythermograph 33

1. NOAA NMFS HAWAIIAN QUEEN Cruise 144, July 1974, 6 days
2. NODC Record No. R390179, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 35, expendable bathythermograph 35

1. NOAA NMFS IDAHO Cruise 24, September 1973, 7 days
2. NODC Record No. R390342, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 86, 87, 90, 127, 128, 129, 130
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 20, expendable bathythermograph 20

1. NOAA NMFS MARIPOSA Cruise 39, March 1974, 7 days
2. NODC Record No. R390187, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 17, 52, 53, 88, 316, 352, 353
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 27, expendable bathythermograph 27

1. NOAA NMFS MARIPOSA Cruise 39, February 1974, 6 days
2. NODC Record No. R390186, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 16, 52, 88, 320, 256, 357
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 31, expendable bathythermograph 31

1. NOAA NMDS MARIPOSA Cruise 39, March 1974, 5 days
2. NODC Record No. R390188, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 22, expendable bathythermograph 22

1. NOAA NMFS MARIPOSA Cruise 39, January-February 1974, 5 days
2. NODC Record No. R390185, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 86, 87, 88, 120, 121, 122
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 24, expendable bathythermograph 24

1. NOAA NMFS MARIPOSA Cruise 40, March 1974, 5 days
2. NODC Record No. R390189, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 86, 87, 88, 120, 121, 122
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 25, expendable bathythermograph 25

1. NOAA NMFS MARIPOSA Cruise 40, April-May 1974, 5 days
2. NODC Record No. R390190, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 25, expendable bathythermograph 25

1. NOAA NMFS MARIPOSA Cruise 41, May 1974, 5 days
2. NODC Record No. R390191, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 86, 87, 88, 120, 121, 122
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 25, expendable bathythermograph 25

1. NOAA NMFS MARIPOSA Cruise 41, May 1974, 5 days
2. NODC Record No. R390192, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 26, expendable bathythermograph 26

1. NOAA NMFS MARIPOSA Cruise 42, May-June 1974, 5 days
2. NODC Record No. R390193, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 86, 87, 88, 120, 121, 122
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 23, expendable bathythermograph 23

1. NOAA NMFS MARIPOSA Cruise 42, June 1974, — days
2. NODC Record No. R390194, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 25, expendable bathythermograph 25

1. NOAA NMFS MARIPOSA Cruise 44, July 1974, 5 days
2. NODC Record No. R390195, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 86, 87, 88, 120, 121, 122
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 22, expendable bathythermograph 22

1. NOAA NMFS MARIPOSA Cruise 44, July 1974, 5 days
2. NODC Record No. R390196, Northeast Pacific
3. McLain, D. (NSF IDOE/ONR) Marsden Squares 87, 88, 121, 122, 123
4. NSF Grant No. AG-256, XBT Pacific Ships of Opportunity, NORPAX

Physical oceanography: discrete surface salinity measurements 24, expendable bathythermograph 24

International Southern Ocean Studies (ISOS)

1. OSU CAYUSE Cruise C7411-B, November 1974, 1 day
2. NODC Record No. R390201, off Oregon coast
3. Pillsbury, R. (NSF IDOE) Marsden Square 157
4. NSF Grant No. GX-42587, ISOS

Meteorology: occasional standard measurements 1
Dynamics: current meter mooring techniques and material tests

Climate: Long Range Investigation, Mapping, and Prediction (CLIMAP) Study

1. OSU YAQUINA Cruise YALOC 74, Leg 1, October 1974, 11 days
2. NODC Record No. R390208, Northeast Pacific
3. Dymond, J., Corliss, R., Johnson, R. (NSF IDOE/ONR) Marsden Squares 84, 121, 157
4. NSF Grant No. GX-28673, CLIMAP

Meteorology: occasional standard measurements 1
Geology/Geophysics: dredge 10, grab 2, physical analysis of sediments 12
Biology: deep scattering layer (miles) 1500

1. OSU YAQUINA Cruise YALOC 74, Leg 2, October-November 1974, 27 days
2. NODC Record No. R390209, Eastern Tropical Pacific
3. Dymond, J., Moore T. (NSF IDOE) Marsden Squares 48, 51, 52, 84-88, 120
4. NSF Grant No. GX-28673, CLIMAP

Geology/Geophysics: core—soft bottom 26, bathymetry—narrow beam (miles) 5000, magnetism (miles) 3500, physical analysis of sediments 30, geochemistry/geochronology samples (collected on Clarion I.)—
Biology: deep scattering layer (miles) 5000

1. OSU YAQUINA Cruise YALOC 74, Leg 3, November-December 1974, 22 days
2. NODC Record No. R390210, Northeast Pacific
3. Heath, G. (NSF IDOE/ONR/AEC) Marsden Squares 88, 122, 123, 124, 157, 158
4. NSF Grant No. GX-28673, CLIMAP

Physical oceanography: classical oceanographic stations 1
Dynamics: current meter stations 3, current meter duration (days) 9
Geology/Geophysics: core—soft bottom 16, bottom photography 2, suspended sediments—, bathymetry—narrow beam (miles) 1700, magnetism (miles) 500

Seabed Assessment Program

Plate Tectonics and Metallogenesis Studies

1. OSU YAQUINA Cruise YALOC, Leg 7, February-March 1974, 27 days
2. NODC Record No. 08830, Eastern Pacific
3. Johnson, S. (NSF IDOE) Marsden Square 343
4. NSF Grant No. GX-28675, Nazca Plate

Geology/Geophysics: core 16; 2800 miles of seismic refraction, seismic reflection, gravimetry, magnetism, bathymetry—wide beam, and bathymetry—narrow beam

1. OSU YAQUINA Cruise YALOC, Leg 8, March 1974, 9 days
2. NODC Record No. 08831, East Central Pacific
3. Johnson, S. (NSF IDOE) Marsden Squares 89, 307, 308
4. NSF Grant No. GX-28675, Nazca Plate

Geology/Geophysics: 1700 miles of seismic reflection, gravimetry, magnetism, bathymetry—wide beam, and bathymetry—narrow beam
Biology: primary production 1, zooplankton 2

Manganese Nodule Study

1. UW ONAR, January 1975, 1 day
2. NODC Record No. R390376, Puget Sound
3. Murray, J. (NSF IDOE) Marsden Square 157
4. NSF Grant No. GX-———, Manganese Nodules

Geology/Geophysics: pure water samples—

Coastal Upwelling Ecosystems Analysis (CUEA)

1. NOAA OCEANOGRAPHER Cruise RP-2-OC-74, March-May 1974, 47 days
2. NODC Record No. 09145, East Central Atlantic
3. Barbee, Capt. W. D. (NSF IDOE) Marsden Squares 74, 75, 76, 77
4. NSF Grant No. AG-299, JOINT-I (CUEA/CINECA)

Meteorology: occasional standard measurements 127, incident radiation (hours) 210
Physical oceanography: continuous temperature recording (days) 36, classical oceanography stations 162, vertical proviles (STD/CTD) 601, expendable bathythermograph 77
Dynamics: profiling current meter stations 82, current meter stations 22

1. OSU CAYUSE Cruise C7410-C, October 1974, 1 day
2. NODC Record No. R390008, Northeast Pacific
3. Pillsbury, R. (NSF IDOE) Marsden Square 157
4. NSF Grant No. IDO71-04211 (GX-28746), CUEA

Meteorology: occasional standard measurements 1
Dynamics: current meter stations 4, current meter duration (days) 60

1. OSU GILLISS Cruise JOINT-I, Leg 0, February 1974, 19 days
2. NODC Record No. 08850, East Central Atlantic
3. Smith, R. (NSF IDOE) Marsden Squares 2, 38, 74
4. NSF Grant No. GX-33502, JOINT-I (CUEA/CINECA)

Meteorology: surface observations—
Physical oceanography: vertical profiles (STD/CTD) 25, continuous surface temperature—
Dynamics: current meter stations 5, current meter duration (days) 21

1. OSU GILLISS Cruise JOINT-I, Leg 1, March 1974, 17 days
2. NODC Record No. 08851, East Central Atlantic
3. Smith, R. (NSF IDOE) Marsden Squares 38, 74
4. NSF Grant No. GX-33502, JOINT-I (CUEA/CINECA)

Meteorology: surface observations—
Physical oceanography: vertical profiles (STD/CTD) 150
Dynamics: current meter stations 32, current meter duration (days) 20, drogues—

1. OSU GILLISS Cruise JOINT-I, Leg 2, March-April 1974, 19 days
2. NODC Record No. 08852, East Central Atlantic
3. Pillsbury, D. (NSF IDOE) Marsden Squares 38, 74
4. NSF Grant No.'s GX-33502, GX-28746 & GX-32211, JOINT-I (CUEA/CINECA)

Meteorology: surface observations—
Physical oceanography: vertical profiles (STD/CTD) 74, continuous surface temperature—
Dynamics: current meter stations 12, current meter duration (days) 20

1. OSU YAQUINA Cruise Y7406-C, June 1974, 6 days
2. NODC Record No. 08958, off Oregon coast
3. Caldwell, D. (NSF IDOE) Marsden Square 157
4. NSF Grant No. GX-33502, CUEA

Meteorology: surface observations—
Physical oceanography: classical oceanographic stations 7, vertical profiles (STD/CTD) 30, temperature microstructure 25
Dynamics: profiling current meter 19

1. OSU CAYUSE Cruise C7407-AA, July 1974, 1 day
2. NODC Record No. 08950, off Oregon coast
3. Smith, R. (NSF IDOE) Marsden Square 157
4. NSF Grant No. CX-33502, CUEA

Meteorology: surface observations—
Dynamics: gear recovery—

1. OSU YAQUINA Cruise Y7408-A, August 1974, 4 days
2. NODC Record No. R390021, off Oregon coast
3. Smith, R./D. Caldwell NSF IDOE) Marsdon Square 157
4. NSF Grant No.'s GX-33502 & GX-23336, CUEA

Meteorology: occasional standard measurements 1
Physical oceanography: vertical profiles (STD/CTD) 57, vertical temperature microstructure 26

1. OSU YAQUINA Cruise Y7409-A, September 1974, 2 days
2. NODC Record No. R390026, off Oregon coast
3. Smith, R. (NSF IDOE) Marsden Square 157
4. NSF Grant No. GX-33502, CUEA

Meteorology: air-sea interface (days) 30, occasional standard measurements 1
Physical oceanography: vertical profiles (STD/CTD) 11
Dynamics: current meter stations 1, current meter duration (days) 30

1. OSU YAQUINA Cruise Y7409-B, September 1974, 3 days
2. NODC Record No. R390025, off Oregon coast
3. Caldwell, D. E. Barton (NSF IDOE) Marsden Square 157
4. NSF Grant No. GX-23336 & GX-33502, CUEA

Meteorology: occasional standard measurements 1
Physical oceanography: vertical profiles (STD/CTD) 58, temperature microstructure 36
Dynamics: profiling current meter 1, current meter duration (days) 1

1. OSU CAYUSE Cruise C7410-C, October 1974, 1 day
2. NODC Record No. R390008, off Oregon coast
3. Pillsbury, D. (NSF IDOE) Marsden Square 157
4. NSF Grant No. GX-28746, CUEA

Meteorology: occasional standard measurements 1
Dynamics: current meter stations 1, current meter duration (days) 60

1. UW ATLANTIS II Cruise 82, March-May 1974, 84 days
2. NODC Record No. 08901, off NW coast of Africa
3. Barber, R., R. Haedrich, R. Dugdale, J. Kelly (NSF IDOE) Marsden Square 74
4. NSF Grant No. various, JOINT-I (CUEA/CINECA)

Meteorology: upper air observations—, incident radiation 60, systematic standard measurements—

Physical oceanography: classical oceanographic stations 177, transparency 100
Chemical oceanography: oxygen 150, phosphates 177, nitrates 177, nitrites 177, silicates 177, chlorinity 177
Pollution: chlorinated hydrocarbons—
Geology/Geophysics: grab—, sampling by divers—, physical analysis of sediments—, chemical analysis of sediments—
Dynamics: currents measured from ship drift—
Biology: primary productivity 45, phytoplankton pigments 45, particulate organic carbon 45, particulate organic nitrogen 45, dissolved organic matter—, pelagic bacteria and microorganisms—, phytoplankton—, zooplankton—, nekton—, pelagic eggs and larvae—, pelagic fishes—, benthic bacteria and microorganisms—, commercial demersal fishes—, acoustical reflections on marine organisms—, ATP-ADP-AMP concentrations—, zooplankton and nekton excretion—, towed zooplankton counter—, laser particle count of suspended particulates including phytoplankton—, particulate silicate, Si^{29}—, pigmentation—, enzymes, ETS, GDH, protein—
Biological studies: identification—, biomass determination —, description of communities—, exploratory fishing—

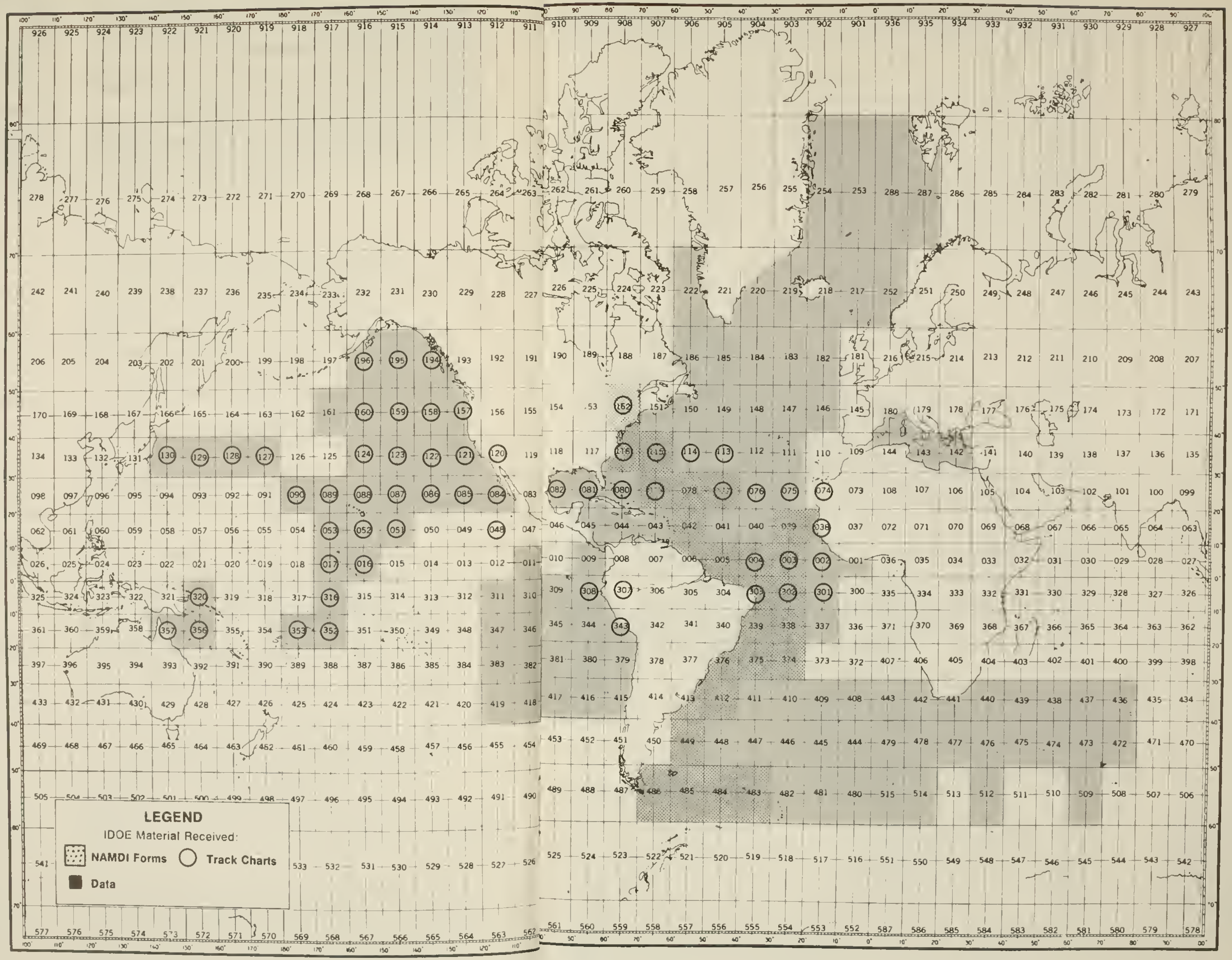

Chart of 10° by 10° geographic areas (Marsden Squares) within which were collected data and information reported in this publication and received by NOAA Environmental Data Service. *Note:* Data and NAMDI/ROSCOP forms are not necessarily received at the same time.

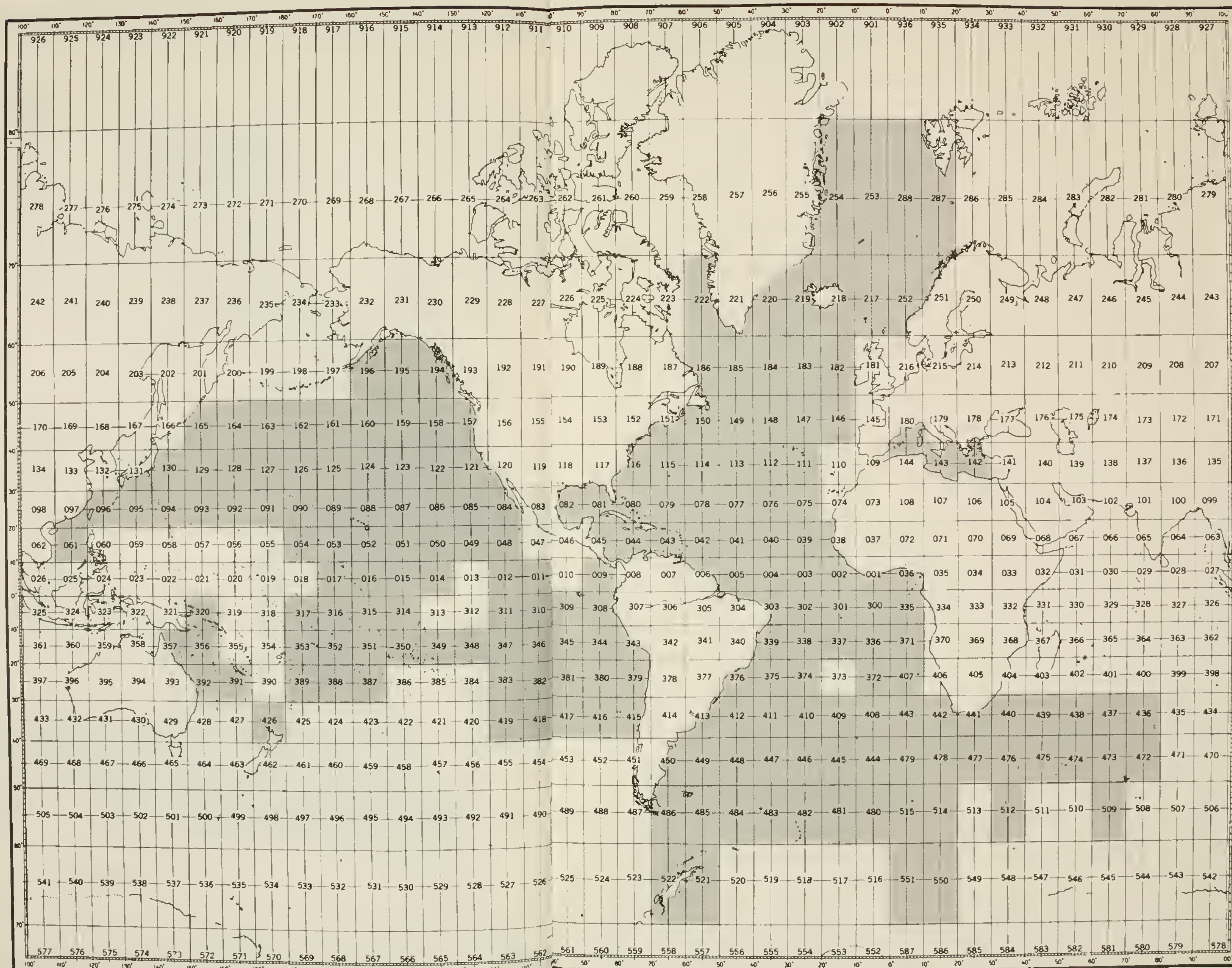

Chart of 10° by 10° geographic areas (Marsden Squares) within which were collected data received by NOAA Environmental Data Service during the period January 1970-April 1975 (shaded squares) resulting from IDOE-sponsored research.

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
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